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Determinants of tuberculosis in Brazil: from conceptual framework to practical application

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ABSTRACT

Objective. *To leverage a conceptual analytical model for TB determination to identify factors that influence emergence of new cases of tuberculosis (TB) and poor TB treatment outcomes in Brazil.*

Methods. *This was a cross-sectional study based on data from Brazil's Notifiable Disease Surveillance System database (SINAN). It included all confirmed, incident TB cases reported in Brazil in 2007 – 2011: a total of 432 958 TB cases, of which 318 465 cases with complete data on treatment outcomes were included. Analysis to explain the causal network that influences TB treatment outcomes was based on a theoretical model for determining TB. Adjusted analyses were used to assess the model fit. Hierarchical logistic regression was used to model the dichotomous TB outcome; hierarchical polytomous regression was used for multinomial TB outcome.*

Results. *Of the 318 465 TB cases included, 222 186 (69.8%) were classified as "cured" and 96 279 (30.2%) as "treatment failure." Among the latter, 37 604 (11.8%) abandoned treatment; 13 193 (4.1%) died due to TB; 15 440 (4.8%) died due to causes other than TB; 28 848 (9.1%) were transferred to another municipality; and 1 194 (0.4%) developed multidrug-resistant TB. The dichotomous models were more likely to show spurious associations when compared with the polytomous model. In the polytomous model, individuals assigned to Directly Observed Treatment Short-course were more likely to be cured than others.*

Conclusions. *Theoretical models are dynamic structures that need ongoing re-evaluation according to new findings; therefore, this is not a definitive proposal for a TB determination model or analysis plan, but rather a proposal that, at present, is adequate in Brazil and has the potential to be extrapolated or adapted to other areas.*

Key words Tuberculosis, epidemiology; health surveillance; data analysis; multivariate analysis; social determinants of health; Brazil.

Historically, which factors have determined the emergence of new cases of tuberculosis (TB) and poor TB treatment outcomes? Studies that attempt to address this question point to the multicausal framework of the disease and describe the biological and molecular aspects of *Mycobacterium tuberculosis*, the host-immune response, conditions over the life-course to which individuals are exposed, and relevant political, economic, and sociocultural issues (1, 2).

The causal complex of TB may be expressed as follows: proximal causes are related to aspects of the host-pathogen interaction; intermediate causes are intricately related to health services and TB control policies; and distal causes are those that describe the socioeconomic and cultural contexts that give rise to and exacerbate the disease. Based on these assumptions, Maciel (2) proposes a theoretical model to determine the disease, taking into account factors previously shown to be relevant in seminal studies of the disease in Brazil (3–8). An adaptation of Maciel's model (2) is shown in Figure 1. It is based on a proposal of interdependence that combines three axes of vulnerability: the individual, the health system, and the social context (9). However, in practice, this model is difficult to implement, as there are further temporal and spatial networks that simultaneously act on the individual.

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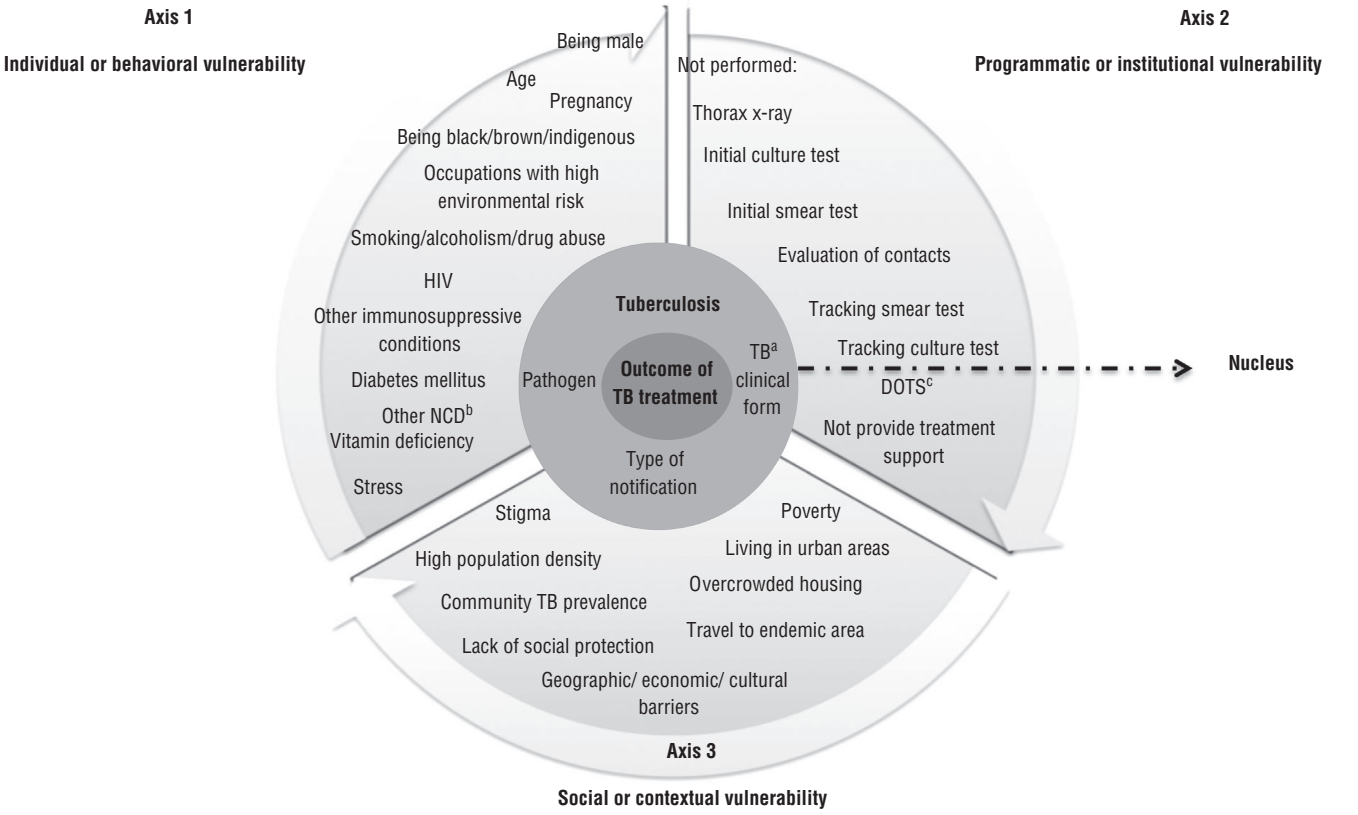
FIGURE 1. Conceptual model for tuberculosis determination in Brazil



[a] Tuberculosis.
[b] Noncommunicable disease.
[c] Directly Observed Treatment Short-course.

TB is a priority for the Ministry of Health of Brazil. The main strategy for TB control is thorough implementation of Directly Observed Treatment Short-course (DOTS), in addition to a firm political commitment, case detection by sputum smear, standardized treatment, a regular and uninterrupted supply of standardized anti-tubercular drugs, and a consistent and reliable case-reporting system (10). The *Sistema de Informação de Agravos de Notificação* (Notifiable Disease Surveillance System database; SINAN) offers detailed information on patients diagnosed with incident TB and is considered a proxy of disease incidence (10). Thus, this study aimed to propose and implement a conceptual analytical model for TB determination based on data available from SINAN.

MATERIALS AND METHODS

This was a cross-sectional study based on data from SINAN, including all confirmed, incident TB cases reported in Brazil between 2007 and 2011. SINAN was developed in Brazil in the 1990s to collect and disseminate important notifiable disease information to health professionals and government bodies. With respect to TB, SINAN includes sociodemographic and health characteristics, as well as features of TB and information describing TB treatment (11, 12). Several analyses of the completeness and validity of SINAN data have been performed and suggest a sufficient number of cases and a high degree of reliability (13).

Theoretical model

Several models were fit and adapted to describe TB determinants based on the theoretical model developed by Maciel (2) (Figure 1). The model that best explained the causal network for the outcome is shown in Figure 2, where TB determinants are arranged hierarchically according to previous knowledge describing their determination relation and temporal ordering.

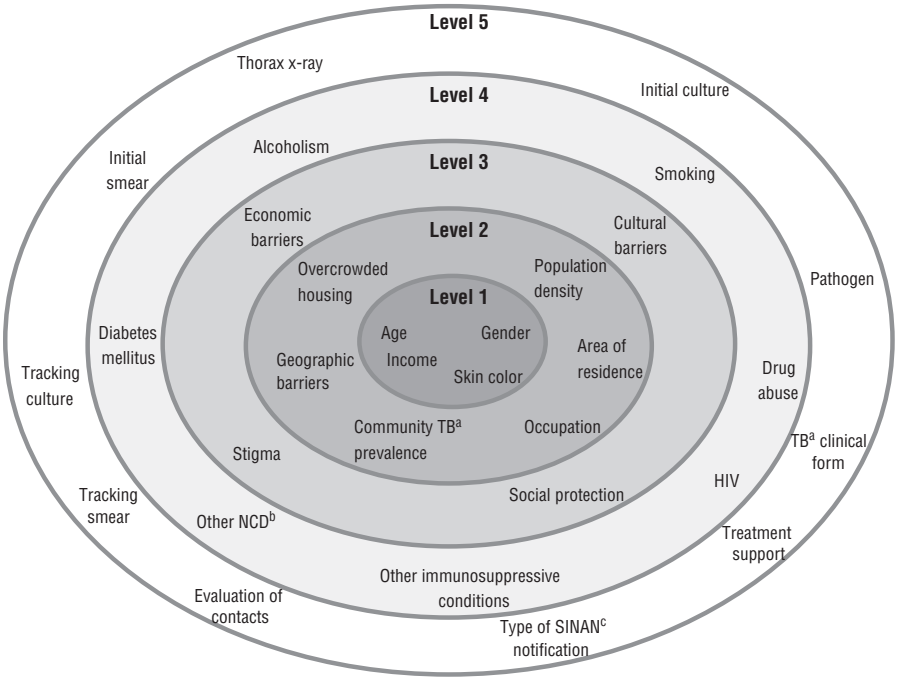
Study population

In 2007–2011, SINAN received reports of 432 958 TB cases. Of these, 318 465 individual's treatment outcomes were included in the analysis; 114 493 were excluded due to incomplete treatment outcome or other inadequate data. TB treatment outcome was dichotomized (cure / treatment failure), as well as a multinomial variable (cure / abandonment / death from TB / death from other causes / development of multidrug-resistant tuberculosis [MDR-TB]).

Variables

In order to evaluate the fit of the proposed theoretical model, the following variables, all of which are available in SINAN, were studied and incorporated into both the nucleus and the multiple axes of the model:

FIGURE 2. Hierarchical model of tuberculosis determinants



[a] Tuberculosis.
[b] Non-communicable disease.
[c] Notifiable Disease Surveillance System database.

TABLE 1. Distribution of variables in the Information System for Notifiable Diseases database (SINAN) in a hierarchical model of tuberculosis (TB) determinants, Brazil, 2007–2011

Hierarchy level	SINAN variable
Level 1	Age group Skin color Gender Schooling
Level 2	Area of residence Institutionalization
Level 3	Alcoholism Diabetes mellitus Mental disease HIV/AIDS
Level 4	Type of SINAN notification Initial smears results Initial culture results Clinical form of TB
Level 5	If under Directly Observed Treatment Short-course

- Individual vulnerability axis: patient age; education level; skin color/ethnicity; the comorbidities of mental illness, diabetes, alcoholism, AIDS/HIV, and other diseases; and pregnancy.
- Programmatic vulnerability axis: initial smear results (as well as presence or absence of the diagnostic test); initial culture results; tuberculin skin test (TST); thoracic x-ray; histopathology; prescribed anti-TB drugs; whether or not disease transmission was due to the patient's professional environment; number of patient contacts indicated by patient and diagnosis; DOTS; and smear-tracking results.
- Social vulnerability axis: location of patient residence; area of residence; institutionalization; and occupation.
- Nucleus variables were: type of treatment; clinical form of TB; and TB treatment outcome (14).

Data analysis

Adjusted analyses were used to assess the model fit. Hierarchical logistic regression was used to model the dichotomous TB outcome, whereas hierarchical polytomous regression was used for multinomial TB outcome. Polytomous regression is a useful technique to simultaneously model the probabilities of an outcome with multiple categories. The method can uncover associations that are otherwise obscured by transformation of a multinomial outcome variable into a dichotomous outcome (15, 16). The "cure" category was included as an outcome for both analyses. This type of modeling is relatively robust, lacking restrictions on the distribution of the outcome and has been used in models that depict the outcome as either ordinal or nominal polytomous (17). As such, when the outcome of TB treatment is categorized, a multinomial approach also allows for inclusion of multiple covariates in the same model. This allows for the identification of individual risk factors within each subgroup of the outcome (15, 18).

In order to overcome the restrictions of linear models (otherwise rigid and compartmentalized), hierarchical models have been used when distal factors (antecedents) influence the intermediate factors that assert an influence on more proximal factors (those that act directly on the outcome). As such, it is possible to include a variety of factors according to their temporal ordering in addition to their influence on the outcome, without necessitating ignorance of the interconnectedness of the antecedents.

The process of statistical analysis and interpretation of results is different in hierarchical modeling. The introduction of each of the variables occurs in stages, starting with the variables at the most distal level and simultaneously introducing variables at the same level. The effect of each variable on the outcome is interpreted as having been adjusted for all the variables that belong to the hierarchical levels above it (distal), as well as for the variable's effects that coexist on the same level. Table 1 shows the variables introduced at each level as illustrated in Figure 2.

For the various comorbidities of alcoholism, diabetes, mental illness, and HIV/AIDS, as well as the assignment of DOTS, a field left blank or marked as 'ignored' was considered an absence of the respective comorbidity or not being assigned to DOTS. Results are presented as odds ratios (OR) with 95% Confidence Intervals (95%CI). Analyses were performed using Stata® version 12.0 (StataCorp LP, College Station, Texas, United States).

Ethics

The Research Ethics Committee at the Universidade Federal do Espírito Santo's Center for Health Sciences (Vitória, Espírito Santo, Brazil) approved this study. To ensure patient anonymity

and privacy, no personal identifiers were included in the analysis.

RESULTS

This study analyzed 318 465 TB cases reported in Brazil from 2007–2011, of which 222 186 (69.8%) were classified as "cured" and 96 279 (30.2%) as "treatment failure." Among the latter, 37 604 (11.8%) abandoned treatment; 13 193 (4.1%) died due to TB; 15 440 (4.8%) died due to causes other than TB; 28 848 (9.1%) were transferred to another municipality; and 1 194 (0.4%) developed MDR TB.

Adjusted Odds Ratios (OR) for each of characteristics associated with TB outcome are shown in Table 2. Analyses of the outcome with artificially-created grouped categories often resulted in a spurious association.

Individuals more than 60 years of age had higher odds of death from TB (OR 7.97; 95%CI = 7.15–8.89) or death from other causes (OR 4.8; 95%CI = 7.24–8.93). However, these individuals also were less likely to abandon their treatment (OR 0.57; 95%CI = 0.54–0.61) compared to those who were less than 20 years old.

In the dichotomous model, males were less likely to abandon treatment (OR 0.76; 95%CI = 0.75–0.77). In the polytomous model, males were more likely to experience all adverse outcomes, except development of MDR TB (OR 1.1; 95%CI 0.89–1.14), but this result was not statistically significant.

Individuals institutionalized in prisons were less likely to abandon treatment (OR 0.68; 95%CI = 0.64–0.71), die from TB (OR 12.56; 95%CI = 0.50–0.63), or die from any other causes (OR 0.70; 95%CI = 0.64–0.76).

In the polytomous analysis, alcoholism was associated with a greater occurrence of all outcomes. The co-presence of diabetes and tuberculosis was also associated with a higher rate of treatment compliance (OR 0.68; 95%CI = 0.64–0.73). Among individuals with HIV/AIDS, the odds of death from TB were 4.7 (95%CI = 3.88–4.27), and from other causes, 11.10 (95%CI = 10.65–11.54)

When compared to individuals identified as new cases, those who had relapsed after previous treatment (9.43 OR; 95% CI = 8.13–10.95), had returned after abandoning treatment (OR 9.14; 95% CI = 7.67 – 10.88), or had transferred to another municipality (OR 6.44; 95%CI = 5.43–7.63) were more likely to develop MDR TB. In contrast, individuals with extrapulmonary TB had 68% lower odds of developing MDR TB (95%CI = 0.21–0.47).

In the polytomous model, individuals assigned to DOTS were more likely to be cured than those with other TB treatment outcomes: abandonment (OR 0.52; 95%CI = 0.51–0.54), death from TB (OR 0.50; 95%CI = 0.48–0.53), death from other causes (OR 0.68; 95%CI = 0.65–0.71), and development of MDR TB (OR 0.84; 95%CI = 0.75–0.95).

DISCUSSION

The use of conceptual models has become widespread. Models are widely considered to be a fundamental element in the research process and in epidemiology because they simplify and facilitate a thorough understanding of the various contexts and multi-dimensional mechanisms that lead to disease (19). Although the first conceptual models were based on the natural history of communicable diseases (1), today they are used in fields that range from health policy evaluation (20) to both communicable (21, 22) and non-communicable (3) diseases, and other disciplines that examine the influence of natural phenomena on the life of the individual (23).

Since identification of *M. tuberculosis* as the causal agent for the disease, various models for its determination have been proposed. These have ranged from basic models based on a single etiology (24, 25) to more advanced models that attempt to account for multiple causes, such as the social determinants of health (2, 26). However, most studies do not consider these models and lack details on how the analysis was carried out. This fact has dramatically hindered a comprehensive understanding of the causal chain of determination of TB, as well as the best interpretation of the model's results and respective measures of association.

TB treatment outcomes in Brazil

TB incidence in Brazil has decreased roughly 1.4% annually since 2001. In 2010, TB incidence was reported as 37.7 / 100 000 individuals and TB mortality as 2.4 / 100 000 (10). TB treatment outcome has been thoroughly studied by researchers in Brazil (4, 27, 28) as well as those hailing from countries and regions with dramatically different TB disease burdens (6, 29). Despite this, few studies have explicitly considered different categories of TB treatment outcomes (30, 31).

The findings of the present study showed several factors were associated with being less likely to abandon TB treatment: being older in age; self-identifying as indigenous or of Asian ethnicity; having participated in or completed higher education (beyond high school); not living in a rural area; being institutionalized in a prison; having diabetes; having extrapulmonary TB; and being assigned to DOTS.

In contrast, the following factors increased the likelihood of abandoning treatment: male gender; being institutionalization in a place other than a prison (e.g., orphanage or psychiatric clinic); having alcoholism or HIV/AIDS; being a relapsed case; returning to treatment after having abandoned it; having unknown treatment completion status; and a positive sputum culture.

Death from TB was more likely among those who were older than 20 years; male; of black or brown ethnicity; not being a new TB case; being illiterate; living in a rural area; being institutionalized in a place other than prison (e.g., orphanage or psychiatric clinic); having alcoholism, mental illness, or HIV/AIDS; a positive sputum culture; the pulmonary form of the disease; and not assigned to DOTS.

With respect to non-TB related causes of death, the odds were higher for those who were older than 20 years; male; of Caucasian ethnicity; illiterate; living in a rural area; being institutionalized in a place other than a prison (e.g., an orphanage or psychiatric clinic); having alcoholism, diabetes, mental illness, or HIV / AIDS; returning to treatment after having abandoned it; unknown treatment completion status; a positive sputum culture; having a concomitant form of the disease; and not being assigned to DOTS.

Factors for those more likely to develop MDR TB were being 20–59 years of age; living in a rural area; having alcoholism, diabetes, or HIV/AIDS; being a relapsed case; having returned after abandoning previous treatment; having transferred away from the treatment center; a positive sputum culture; having pulmonary TB; and not being assigned to DOTS.

TABLE 2. Logistic and polytomous hierarchical models of association between sociodemographic and clinical characteristics of individuals with tuberculosis (TB) and tuberculosis treatment outcome, Brazil, 2007–2011

Characteristic (*n*)	Cured vs Failure	Cured vs Abandonment	Cured vs Death from TB	Cured vs Death from other cause	Cured vs MDR TB[c]
	OR[a] (95% CI[b])	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Level 1					
Age group (318 465)					
< 20 years	Ref.[d]	Ref.	Ref.	Ref.	Ref.
20–39 years	0.67 (0.65–0.69)	1.57 (1.50–1.64)	1.92 (1.72–2.14)	2.37 (2.14–2.63)	2.09 (1.58–2.78)
40–59 years	0.72 (0.70–0.74)	0.95 (0.91–1.00)	3.93 (3.53–4.38)	4.16 (3.76–4.62)	2.30 (1.73–3.07)
≥ 60 years	0.59 (0.57–0.61)	0.57 (0.54–0.61)	7.97 (7.15–8.89)	8.04 (7.24–8.93)	1.50 (1.07–2.09)
Gender (318 465)					
Female	Ref.	Ref.	Ref.	Ref.	Ref.
Male	0.76 (0.75–0.77)	1.48 (1.44–1.51)	1.39 (1.34–1.45)	1.25 (1.20–1.29)	1.01 (0.89–1.14)
Skin color (275 109)					
Caucasian	Ref.	Ref.	Ref.	Ref.	Ref.
Black	0.79 (0.77–0.81)	1.49 (1.44–1.54)	1.24 (1.17–1.32)	0.94 (0.89–1.00)	1.01 (0.85–1.20)
Brown	0.86 (0.84–0.87)	1.17 (1.14–1.20)	1.17 (1.12–1.23)	0.79 (0.76–0.82)	0.91 (0.80–1.03)
Asian/ indigenous	1.05 (0.99–1.11)	0.91 (0.83–0.99)	0.99 (0.87–1.13)	0.65 (0.57–0.75)	0.38 (0.21–0.70)
Schooling (196 869)					
Illiterate	Ref.	Ref.	Ref.	Ref.	Ref.
1–4 years	1.12 (1.08–1.16)	0.91 (0.86–0.96)	0.83 (0.77–0.89)	0.87 (0.81–0.94)	1.19 (0.90–1.58)
5–8 years	1.08 (1.04–1.12)	0.95 (0.89–1.00)	0.79 (0.73–0.85)	0.88 (0.81–0.96)	1.59 (1.20–2.12)
> 8 years	1.88 (1.81–1.96)	0.46 (0.43–0.49)	0.50 (0.45–0.55)	0.56 (0.51–0.61)	0.82 (0.60–1.11)
Not applicable	1.25 (1.17–1.34)	0.55 (0.49–0.61)	1.23 (1.06–1.42)	1.38 (1.20–1.58)	0.27 (0.11–0.70)
Level 2					
Area of residence (238 067)					
Rural	Ref.	Ref.	Ref.	Ref.	Ref.
Urban	1.36 (1.32–1.40)	0.55 (0.53–0.58)	0.67 (0.62–0.72)	0.90 (0.84–0.96)	0.66 (0.52–0.83)
Peri-urban	1.12 (1.01–1.23)	0.63 (0.54–0.75)	0.77 (0.60–0.98)	0.78 (0.61–0.99)	0.90 (0.46–1.74)
Institutionalization (266 136)					
None	Ref.	Ref.	Ref.	Ref.	Ref.
Prison	1.23 (1.19–1.27)	0.68 (0.64–0.71)	0.56 (0.50–0.63)	0.70 (0.64–0.76)	0.82 (0.63–1.08)
Other	0.78 (0.75–0.81)	1.28 (1.21–1.36)	1.46 (1.34–1.59)	1.35 (1.23–1.47)	0.86 (0.62–1.20)
Level 3					
Alcoholism (318 465)					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	0.55 (0.54–0.56)	2.00 (1.93–2.05)	2.07 (1.98–2.16)	1.39 (1.32–1.45)	1.79 (1.54–2.07)
Diabetes mellitus (318 465)					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	1.06 (1.03–1.10)	0.68 (0.64–0.73)	1.01 (0.94–1.08)	1.10 (1.03–1.17)	1.53 (1.24–1.90)
Mental illness (318 465)					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	0.86 (0.82–0.91)	1.00 (0.92–1.08)	1.41 (1.28–1.56)	1.44 (1.31–1.60)	0.66 (0.42–1.05)
HIV/AIDS (318 465)					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	0.31 (0.31–0.32)	2.07 (2.00–2.14)	4.07 (3.88–4.27)	11.10 (10.65–11.54)	1.53 (1.28–1.84)
Level 4					
Type of SINAN[e] notification (318 465)					
New case	Ref.	Ref.	Ref.	Ref.	Ref.
Relapse	0.78 (0.76–0.81)	1.48 (1.41–1.55)	1.32 (1.23–1.41)	1.00 (0.93–1.07)	9.43 (8.13–10.95)
Return after abandonment	0.35 (0.34–0.36)	5.64 (5.44–5.85)	2.10 (1.95–2.26)	1.33 (1.22–1.44)	9.14 (7.67–10.88)
Unknown	0.33 (0.29–0.37)	2.15 (1.65–2.80)	11.57 (9.54–14.03)	5.02 (3.97–6.36)	2.02 (---)
Transfer	0.74 (0.72–0.76)	1.05 (0.99–1.11)	1.26 (1.16–1.36)	0.81 (0.75–0.89)	6.44 (5.43–7.63)
Smear test (258 648)					
Negative	Ref.	Ref.	Ref.	Ref.	Ref.
Positive	1.04 (1.02–1.06)	1.07 (1.03–1.10)	0.88 (0.84–0.93)	0.64 (0.61–0.66)	2.41 (2.00–2.91)
Culture test (61 130)					
Negative	Ref.	Ref.	Ref.	Ref.	Ref.
Positive	0.74 (0.71–0.77)	1.51 (1.42–1.61)	1.53 (1.37–1.71)	1.35 (1.24–1.48)	6.46 (4.59–9.08)
Clinical form of TB (318 465)					
Pulmonary	Ref.	Ref.	Ref.	Ref.	Ref.
Extrapulmonary	1.15 (1.12–1.17)	0.69 (0.67–0.72)	0.69 (0.65–0.74)	0.95 (0.90–0.99)	0.32 (0.21–0.47)
Pulmonary + Extrapulmonary	0.71 (0.68–0.74)	0.97 (0.91–1.04)	2.03 (1.88–2.20)	1.96 (1.83–2.10)	0.73 (0.49–1.09)
Level 5					
DOTS[f] (318 465)					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	1.58 (1.55–1.60)	0.52 (0.51–0.54)	0.50 (0.48–0.53)	0.68 (0.65–0.71)	0.84 (0.75–0.95)

[a] Odds Ratio.
[b] 95% Confidence Interval.
[c] Multidrug-resistant tuberculosis.
[d] Reference.
[e] Notifiable Disease Surveillance System database
[f] Directly Observed Treatment Short-course.

Limitations

This study's importance and relevance come from its thorough assessment of TB treatment outcomes using a nationally representative TB case database and its detailed, conceptual, model-based analysis that identified TB determinants in Brazil. There are several important limitations, however, that should be considered. Of the total TB cases, 26% of notified individuals were excluded for insufficient TB treatment outcome data. That said, it is also unlikely that this affected the reported associations since missing data were not differentially distributed among the variables. There were several other variables that presented missing data as well, and those cases were also excluded due to the study's already high statistical power.

The proposed theoretical model has described the multiple TB determinants, however the absence of several important variables in the SINAN database precludes evaluation of several important aspects of this causal framework. Future studies that combine data on the characteristics of the bacillus (such as genotyping) and information from social programs, governmental or non-governmental, with existing income data on TB patients could allow for the model to be used to identify other important determinants and/or modify those already identified.

Conclusions

The main takeaway from these findings is the need for analysis plans that are supported by theoretical models. Theoretical models are dynamic structures that must be re-evaluated as new information is obtained; they are subject to continual adaptation according to new findings, as well as more complete and discrete information describing outcomes or exposures. Furthermore, the models may vary according to an emphasis on certain desired aspects, being general or more specific. As such, this article is not a definitive model for TB determination or analysis, but rather a proposal that is currently adequate in Brazil, yet can also be extrapolated or adapted to other contexts.

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Conflicts of interest. None.

Disclaimer. Authors hold sole responsibility for the views expressed in the manuscript, which may not necessarily reflect the opinion or policy of the *RPSP/PAJPH* and/or PAHO.

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RESUMEN

Determinantes de la tuberculosis en el Brasil: del marco conceptual a la aplicación práctica

Objetivo. Hacer uso de un modelo analítico conceptual para la determinación de la tuberculosis con objeto de establecer los factores que influyen en la aparición de nuevos casos de tuberculosis (TB) y en los resultados deficientes del tratamiento antituberculoso en Brasil.

Métodos. Se llevó a cabo un estudio transversal con base en los datos de la base de datos del Sistema de Vigilancia de Enfermedades de Notificación Obligatoria del Brasil (SINAN). Incluyó a todos los nuevos casos de tuberculosis confirmados y notificados en Brasil del 2007 al 2011: un total de 432 958 casos de tuberculosis, 318 465 de los cuales contaban con datos completos sobre los resultados del tratamiento. El análisis para explicar la red causal que influye en los resultados del tratamiento antituberculoso se basó en un modelo teórico para la determinación de la tuberculosis. Se usaron análisis ajustados para evaluar el ajuste del modelo. Mediante regresión logística jerárquica se modeló el resultado dicotómico de la tuberculosis; y se utilizó la regresión jerárquica politómica para el resultado polinómico de la tuberculosis.

Resultados. De los 318 465 casos de tuberculosis incluidos, 222 186 (69,8%) se clasificaron como "curados" y 96 279 (30,2%) como "fracasos terapéuticos". De estos últimos, 37 604 (11,8%) abandonaron el tratamiento; 13 193 (4,1%) murieron como consecuencia de la tuberculosis; 15 440 (4,8%) murieron por causas diferentes a la tuberculosis; 28 848 (9,1%) fueron trasladados a otro municipio; y 1 194 (0,4%) contrajeron tuberculosis multirresistente. Los modelos dicotómicos mostraron asociaciones espurias con mayor probabilidad que el modelo politómico. En el modelo politómico, los pacientes asignados a un tratamiento breve bajo observación directa mostraron mayores probabilidades de curación que otros.

Conclusiones. Los modelos teóricos son estructuras dinámicas que requieren una permanente reevaluación según los nuevos resultados; por consiguiente, esta no es una propuesta definitiva de un modelo de determinación de la tuberculosis o un plan de análisis, sino que más bien es una propuesta que, actualmente, resulta adecuada en Brasil y puede ser extrapolada o adaptada a otras zonas.

Palabras clave Tuberculosis, epidemiología; vigilancia sanitaria; análisis de datos; análisis multivariante; determinantes sociales de la salud; Brasil.