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Impact of incarceration on tuberculosis incidence and its interaction with income distribution inequality in Brazil

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Background: Deteriorated conditions in the non-prison population can lead to an approximation of its tuberculosis (TB) risk to that in the prison population. We evaluated the association between incarceration and TB incidence rate and its interaction with population income distribution inequality in Brazilian municipalities (2013–2015).

Methods: We included 954 municipalities with at least one prison. Interaction between the Gini coefficient and prison exposure was analysed in a multiple regression model. We estimated the fraction of TB in the population attributable fraction (PAF) to exposure to prisons according the Gini coefficient.

Results: Compared with the non-prison population, the prisoners had 22.07 times (95% confidence interval [CI] 20.38 to 23.89) the risk of TB in municipalities where the Gini coefficient was <0.60 and 14.96 times (95% CI 11.00 to 18.92) the risk where the Gini coefficient was ≥ 0.60. A negative interaction in the multiplicative scale was explained by a higher TB incidence in the non-prison population in municipalities with a Gini coefficient ≥ 0.60. The PAF ranged from 50.06% to 5.19% in municipalities with Gini coefficients <0.40 and ≥ 0.60, respectively.

Conclusions: Interventions to reduce prison exposure would have an ostensible impact in population TB incidence rates mainly in settings with lower Gini coefficients. In those with extreme inequality in income distribution, strategies focused on mitigating the effects of socio-economic factors should also be prioritized.

Keywords: Gini coefficient, incarceration, interaction, tuberculosis

Introduction

After more than 70 y of available treatment, tuberculosis (TB) control still remains a challenge in low- and middle-income countries.[1] Socio-economic factors contribute substantially to the ongoing epidemic.[2–5] In Brazil, the association between socio-economic factors and TB incidence seems to be explained by household crowding,[5] which may directly favour TB transmission by increasing the contact rate.[6,7]

An extreme of this phenomenon is represented in prisons, where overcrowding has been associated with TB incidence.[8–13] In a systematic review that included 19 studies in eight countries, the incidence rate ratio (IRR) for TB regarding prison exposure exhibited a median of 23, with an important variability between the countries (interquartile range [IQR] 11.7–36.1).[14] This variability may be explained by differences in the population profile in relation to risk factors for TB, strategies for TB screening in those sites and possible effect modifiers.

The monitoring of this association measure is important to evaluate the control of TB transmission in prisons and to estimate the relative importance of these settings as social reservoirs. However, besides the risk in exposed populations, the IRR also depends on the baseline risk in the reference group (non-prison population). Therefore, deteriorated conditions in the non-prison population could lead to a higher TB risk, approaching that observed in the exposed group. In this sense, in poor socio-economic scenarios, the IRR could be lower without actual control of the disease and could also affect the fraction of TB attributable to exposure to prison settings in the total population (i.e. population attributable fraction [PAF]).

This is particularly relevant in Brazil, which has great variability in socio-economic indicators.[15] Possible interactions can lead to the wide variability of estimates. This can affect the defining of priorities, which should be contextualized by decision makers.

Consequently, we estimated the association between incarceration and TB incidence rate and its interaction with income distribution inequality in Brazilian municipalities. Additionally, we calculated the corresponding PAF as a measure of the potential impact on population TB risk of interventions localized in prison settings.

Materials and methods

Setting

Brazil is a middle-income South American country included in the World Health Organization list of the highest TB burden countries.[16] In 2017, 69 569 new TB cases were registered in the country, of which 10.5% were in inmates.[17] In this population, the TB incidence rate was 28 times higher than that in the non-exposed population,[17] and in 2016 the country had the third-largest prison population in the world, with a total of 726 712 people incarcerated.[18]

Study design and population

This was an ecological study of the TB incidence rate. It included the 954 Brazilian municipalities with at least one prison setting in 2014. These municipalities had a total of 1424 prisons and 85 million people $\geq$18 y of age.

Source of data and variables

The number of new TB patients (all clinical forms) in the prison (exposed) and non-prison (non-exposed) populations was obtained from the Brazilian National Information System for Notifiable Diseases (Sinan), a surveillance information system for compulsory TB notification. To reduce distortions in estimates due to case reporting instability in small municipalities, we analysed the data of diagnosed patients in a 3-y period (from 2013 to 2015).

We obtained the non-exposed population by subtracting the prison population from the total population estimated by the Brazilian Institute of Geography and Statistics.[19] The prison population by municipality was extracted from the National Survey of Penitentiary Information[18] and was available for only 2014, so this same value was used for 2013 and 2015.

In Brazil, 18 y is the age at which a person accused of an offense is, as a rule, tried and sentenced as an adult, so we only analysed TB cases of persons $\geq$18 y of age from both populations. Non-exposed population data were available for the study period (2013–2015) only by age categories, including one of 15–19 y. To obtain the estimate of the population $\geq$18 y of age we applied the proportion of the population 18–19 y of age from available data for 2012 into the years 2013–2015.

The socio-economic factors of the municipalities were obtained from the census[19] and the Human Development Atlas,[20] which were available for the 2000 and 2010 census years. Therefore we made a projection of the natural logarithm of the corresponding indicators, which was exponentiated to obtain the predicted values. Since the prison population was available for only 2014, we used the predicted values from this same year for the socio-economic variables.

We considered the Gini coefficient as an indicator of income distribution inequality. We also analysed the following socio-economic indicators that were already associated with TB incidence in Brazil:[5,15] human development index, mean household income per capita, gross domestic product (GDP) per capita, unemployment rate and household crowding (proportion of the population living in households with more than two people per bedroom).[20] The values of the variables mean household income per capita and GDP per capita were converted from the Brazilian currency (real [R$]) to US dollars (US$), according to the average price in 2014, when US$1.00 was worth R$2.35. We also considered the acquired immune deficiency syndrome (AIDS) incidence rate per 100 000 person-years, using Sinan as the data source, in which case the definition was based on Caracas's criteria.[21]

Statistical analysis

Independent variables were described by calculating the median and IQR values.

To verify if there was an interaction compatible with a linear gradient, we explored the association between prison and TB incidence in different quantiles of the Gini coefficient. We found that up to the value of 0.58 the IRRs of the association of TB and prison were similar, therefore we assumed that oscillations in the IRR were random. However, the highest decile of the Gini coefficient (including values between 0.59 and 0.74) exhibited an IRR lower than the other strata (Supplementary Figure S1), so we analysed this variable as dichotomous (<0.60 and $\geq$0.60). We designated the category of Gini coefficient $\geq$0.60 as extreme inequality in income distribution (EIID). In 2015, only seven countries worldwide presented this value (Gabon, Central African Republic, Sierra Leone, Botswana, Lesotho, South Africa and Namibia),[22] but in Brazil, 71 municipalities included in this study presented this value, covering 33 million people. In addition, in 2015 Brazil ranked 17th in the worst Gini coefficient in a list of 162 countries,[22] so this indicator may more properly reflect social disparities in Brazil. Finally, social determinants were already documented as an important factor associated with TB incidence in Brazilian municipalities.[5,15]

To identify a minimal sufficient adjustment set of variables for the association of prison and TB incidence rate, and its interaction with income distribution inequality, we developed a directed acyclic graph (DAG) (Supplementary Figure S2). Interaction was represented in the DAG as recommended by Weinberg.[23] With the exception of the mean household income per capita (Spearman's r=0.11) and the unemployment rate (Spearman's r=0.20), the Gini coefficient correlated with the other variables (Spearman's r>0.60). Those correlated variables were considered potential proxys of socio-economic condition associated with the outcome by the same causal pathway.[24] In addition, we assumed that the AIDS incidence rate per 100 000 person-years and exposure to prison had a common unmeasured cause (risky behaviour tendency), such as, in Brazil, the use of illicit drugs, one of the recent drivers of the human immunodeficiency virus (HIV) epidemic,[25] and their trafficking are the most prevalent cause of imprisonment in the country.[18] Finally, according to previous studies, household crowding can be considered a mediator explaining the effect of socio-economic factors, so, being in the causal pathway, we should not include it in the model to estimate the total effect of income inequality.[5] Therefore the minimum set of variables for adjustment to evaluate the association of prison exposure with the TB incidence rate and its interaction with the Gini coefficient were the unemployment rate and the AIDS incidence rate.

We evaluated the associations using negative binomial regression, because we found overdispersion. First, we performed separate analyses for prison and non-prison populations. Afterward, pooling these populations, we analysed the interaction between the Gini coefficient ($\geq$0.60 vs $<$0.60) and exposure to prison settings in a multiple model. Since prison and non-prison populations in the same municipality share the same context, we also tested a multilevel analysis (Supplementary Table S1).[26]

To evaluate the interaction in the multiplicative scale we calculated the ratio of IRRs[24] with the following formula:

$$ratio\ of\ IRRs = \frac{IRR_{pd}}{IRR_{p0}IRR_{d0}} = \exp\left(\beta_{p\wedge d}\right),$$

where $\boldsymbol{IRR_{p0}}$ represents the IRR for only prison exposure, $\boldsymbol{IRR_{d0}}$ represents the IRR for only EIID exposure, $\boldsymbol{IRR_{pd}}$ represents the IRR for both exposures and $\beta_{p\wedge d}$ represents the coefficient of the interaction term of the concomitant exposures to both prison and EIID, respectively.

For the interaction in the additive scale we calculated the relative excess risk due to interaction (RERI):[27]

$$\mathrm{RERI} = \mathrm{IRR_{pd}} - \left(\mathrm{IRR_{p0}} + \mathrm{IRR_{d0}} - 1\right) = \mathrm{IRR_{pd}} - \mathrm{IRR_{p0}} - \mathrm{IRR_{d0}} + 1.$$

We considered an interaction as positive in the multiplicative and additive scales if the ratio of IRRs was $>$1 and RERI was $>$0, respectively. Interaction analysis was presented as recommended.[28]

The PAF of prison status on TB incidence was calculated both at the municipal level (crude value for each municipality) and by the Gini categories (estimations derived from the multiple models). For that we used two different formulas. With the following formula we calculated the crude PAF for prison status on TB incidence for each municipality:

$$\mathrm{PAF} = \frac{\mathrm{I_p} - \mathrm{I_0}}{\mathrm{I_p}},$$

where I_p is the overall municipality incidence rate of TB (pooling both exposed and non-exposed populations) and I_0 is the incidence rate observed in a non-exposed population of the corresponding municipality.

We plotted the municipality's PAF for prison status on TB incidence distribution according to the prevalence of inmates in the municipality population as well as to the municipality-specific IRR and calculated the corresponding Spearman correlations with their bias-corrected 95% confidence intervals (CIs) estimated by 1000 bootstrap replications. Similar to other correlation coefficients, we interpreted the magnitude of the Spearman coefficient as a measure of the variability of PAF explained by the variability of the exposure prevalence and the strength of the association. Then we compared these two correlation coefficients in order to identify which was the most important factor explaining the variability of PAF.

The second formula was used to estimate the PAF of prison status on TB incidence using the adjusted association measures from the multiple models, by different strata of Gini coefficient:

$$PAF = p'\frac{\theta - 1}{\theta},$$

where p′ is the prevalence of inmates in the total number of TB cases in the corresponding stratum of the Gini and θ is the specific IRR estimated in a multiple regression model for each Gini stratum.

The CI of PAF and interaction measures derived from the multiple models were calculated using a non-linear combination of parameter estimates based on the delta method.[29]

All of the analyses were performed using Stata version 11 (StataCorp, College Station, TX, USA).

Results

A total of 137 698 TB cases were registered in the 954 municipalities during 2013–2015, of which 14 769 (10.73%) were inmates. The median Gini coefficient was 0.50 (IQR 0.46–0.54), human development index was 0.750 (IQR 0.704–0.786), mean household income per capita was US$261.19 (IQR 164.56–350.04), GDP per capita was US$6404.03 (IQR 3696.50–10 365.71), unemployment rate was 5.32% (IQR 3.98–7.22), household crowding was 21.7 (IQR 14.8–28.5) and AIDS incidence rate was 4.69 cases per 100 000 person-years (IQR 0.0–9.42).

In municipalities with EIID (Gini coefficient $\geq$0.60), the TB incidence rate point estimate was highest among the non-exposed population (35.28/100 000 non-prison person-years) and lowest among the prison population (417.01/100 000 prison person-years) when compared with the corresponding populations from the other strata. Consequently, the IRR (prison/non-prison) point estimate was lowest in municipalities with a Gini coefficient $\geq$0.60 (Figure 1).

In multiple models, a Gini coefficient $\geq$0.60 was positively associated with TB incidence in the non-prison population (IRR 1.33 [95% CI 1.17–1.52]), but not in the prison population (IRR 0.89 [95% CI 0.65–1.22]). In both models, the unemployment rate and AIDS incidence rate were positively associated with the TB incidence rate (Table 1).

In the pooled multiple model, compared with the non-prison population, the prison population had 22.07 times (95% CI 20.38 to 23.89) the risk of TB in municipalities where the Gini coefficient was $<$0.60 and 14.96 times (95% CI 11.00 to 18.92) where the Gini coefficient was $\geq$0.60 (Table 2).

Thus a statistically significant negative interaction was observed in the multiplicative scale (ratio of IRR 0.68 [95% CI 0.40 to 0.87]; p<0.001), but not in the additive scale, although the IRR was 2.33 units less than expected on the additive scale

Table 1. Factors associated with the TB incidence rate in municipalities (n=954) according to non-prison and prison populations, Brazil, 2013–2015

Variable	Non-prison population				Prison population			
	IRR crude	(95% CI)	IRR adjusted	(95% CI)	IRR crude	(95% CI)	IRR adjusted	(95% CI)
Gini coefficient ≥0.60 vs <0.60	1.6	1.38 to 1.85	1.33	1.17 to 1.52	1.08	0.8 to 1.48	0.89	0.65 to 1.22
Human development index	1.17	0.54 to 2.53			1.62	0.3 to 8.73		
Mean household income per capita (US$)[a]	1.03	0.76 to 1.39			1.82[b]	0.96 to 3.43		
GDP per capita (US$)	1.00	1.00 to 1.01			1.01	1.00 to 1.02		
Unemployment rate (%)	1.08	1.06 to 1.09	1.08	1.06 to 1.09	1.06	1.02 to 1.09	1.07	1.03 to 1.11
Household crowding (%)	1.02	1.02 to 1.03			1.02	1.01 to 1.02		
Aids incidence rate/100 000 person-years	1.03	1.03 to 1.04	1.03	1.03 to 1.04	1.03	1.01 to 1.04	1.03	1.02 to 1.04

[a] The association measures are presented at each addition of $1000 of the corresponding independent variable.

[b] Inclusion of mean per capita household income in the multiple model of the prison population decreased the IRR of the Gini coefficient to 0.79, but this association remained not statistically significant (95% CI 0.57 to 1.10).

Table 2. Interaction between income distribution inequality and exposure to prison settings on the TB incidence rate in municipalities (n=954), Brazil, 2013–2015

	Non-prison population		Prison population		Ratio of the IRR (95% CI) for prison population within strata of the Gini coefficient
	n with TB/n without TB per million	IRR (95% CI)[a]	n with TB/n without TB per million	IRR (95% CI)[a]	
Gini coefficient					
<0.60	55 734/156.32	1.0	10 812/1.36	22.07 (20.38 to 23.89), p<0.001	22.07 (20.38 to 23.89), p<0.001
≥0.60	67 186/99.47	1.34 (1.13 to 1.60), p=0.001	3957/0.38	20.08 (16.21 to 24.87), p<0.001	14.96 (11.00 to 18.92), p<0.001
Ratio of the IRR (95% CI) for a Gini coefficient ≥0.60 within strata of the population		1.34 (1.13 to 1.60), p=0.001		0.91 (0.71 to 1.11), p=0.40	

Measure of interaction on additive scale: RERI −2.33 (95% CI −6.73 to 2.08), p=0.30.

Measure of interaction on multiplicative scale: ratio of IRR 0.68 (95% CI 0.40 to 0.87), p<0.001.

[a] Adjusted for unemployment rate and AIDS incidence rate using negative binomial regression.

(p=0.30). In the multilevel model, a negative interaction was observed in both the multiplicative (ratio of IRR 0.70 [95% CI 0.63 to 0.79]; p<0.001) and additive scales (RERI −3.54 [95% CI −6.02 to −1.07]; p=0.01) (Supplementary Table S1).

PAF

Crude PAFs for prison status on TB incidence estimated by municipalities were correlated with the prevalence of inmates in the municipality population (Spearman *r*=0.55 [95% CI 0.48 to 0.62]) and with the municipality-specific IRR (Spearman *r*=0.62 [95% CI 0.57 to 0.68]). However, the Spearman correlation coefficient of the IRR was higher than of that of the exposure prevalence (p=0.013) (Figure 2).

The municipal PAF distribution suggests a progressive decreasing trend with an increase in the inequality level of income distribution (Figure 3). The global PAF for prison status on TB incidence was 10.22% (95% CI 10.18 to 10.26) and was progressively lower in scenarios with high income distribution inequality: 50.06% (95% CI 49.29 to 50.82) for a Gini <0.40,

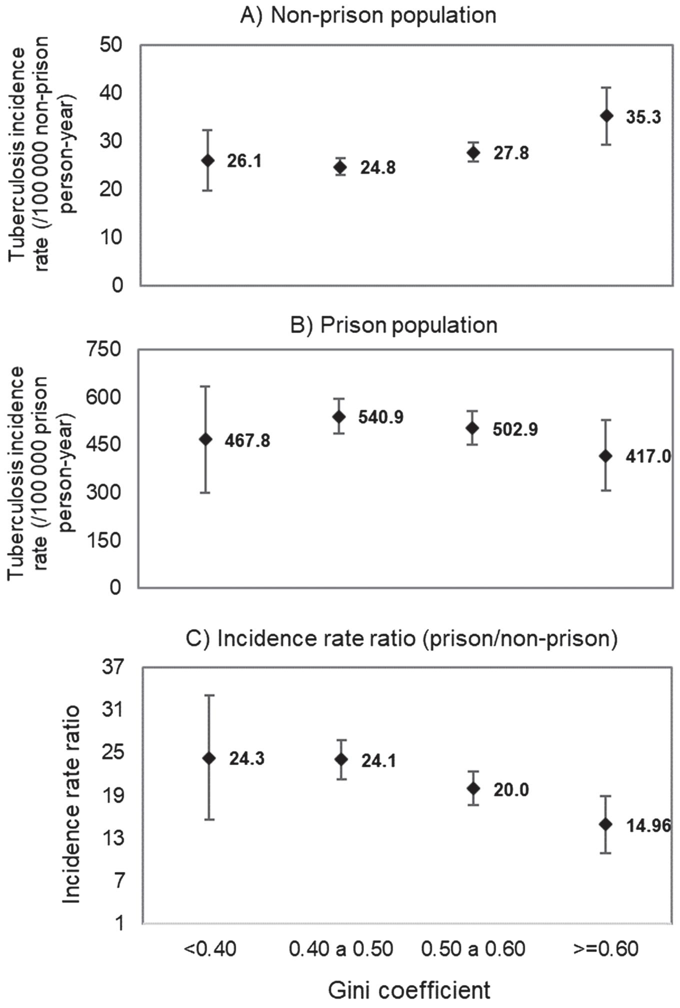

Figure 1. Tuberculosis incidence rate in non-prison and in prison populations; and incidence rate ratio according to Gini coefficient, adjusted by unemployment rate (%) and aids incidence rate/100 000 person-year. Brazil, 2013–2015.

17.51% (95% CI 17.42 to 17.59) for a Gini of 0.40–0.50, 12.24% (95% CI 12.17 to 12.31) for a Gini of 0.50–0.60 and 5.19% (95% CI 5.09 to 5.29) for a Gini $\geq$0.60. These results were obtained from category-specific models adjusted by unemployment rate and AIDS incidence rate, and were similar to the estimates obtained with a multilevel analysis (Supplementary Table S2). The key results of this study are presented in Supplementary Figure S3.

Discussion

Our study showed how the association between incarceration and TB incidence rate varies according to income distribution inequality in Brazilian municipalities. The smaller IRRs in the municipalities with EIID were explained by the increase in the TB incidence rate in the non-prison population and an apparent reduction in the TB incidence rate in the prison population.

In the non-prison population, the Gini coefficient may be associated with the TB incidence rate by different mechanisms. In Brazil, income distribution inequality was strongly correlated with household crowding.[5] This may directly favour TB transmission by increasing the contact rate between *Mycobacterium tuberculosis* and susceptible people.[6,7]

Regarding the prison population, incarceration is associated with TB risk through individual factors, including smoking, alcohol and illicit drug disorders.[30–32] There are also those related to incarceration conditions that lead to malnutrition, stress and anxiety[31–33] and related to contextual factors such as inadequate health services, overcrowding and inadequate ventilation.[8,13,31,34] Other determinants include operational issues such as underdetection of TB cases, difficulties in identifying contacts, inadequate treatment, high rates of transfer-out patients among prisons and low implementation of infection control measures.[35] The socio-economic factors of the municipalities in which the prisons are located may be associated with operational issues in the implementation of active as well as passive case finding in prisons, which could compromise case detection even in high TB risk scenarios.

The PAF is the result of the magnitude of association and prevalence of exposure.[36] If the IRR was constant, the variability of the PAF would be explained only by the exposure prevalence. However, in our study we found that the correlation of the crude municipality PAF of prison status on TB incidence with the IRR was higher than that with exposure to prison settings. This indicates that the IRR heterogeneity was the main determinant of the PAF variability and highlights the importance of identifying the modifiers of the effect (and consequently of the impact) of prison exposure on TB risk.

In contrast to our study, in a systematic review, countries with worse socio-economic conditions had higher IRRs, which seemed to be explained mainly by a higher incidence in the prison population.[14] Despite that, the review found that the PAF of prison status on TB incidence in high-income countries (8.5% [IQR 1.9–17.9]) was higher than that of low- and middle-income countries (6.3% [IQR 2.7–17.2]).[14] This trend of PAF according to socio-economic situations is consistent with our results, which illustrate that inequality affects the relative importance of prison exposure mainly due to the deterioration of non-prison population conditions. In contrast, in better socio-economic scenarios, the relative importance of incarceration becomes more evident as a major contributor of the TB cases in the total population.

Previous studies have found that the AIDS incidence rate is positively associated with the occurrence of new TB cases in prison and non-prison populations.[4,14,35,37,38] TB and HIV act synergistically by amplifying the magnitude of TB,[39] becoming a special challenge for TB control.

The unemployment rate was also positively associated with the TB risk in the non-prison population in the USA,[37] Spain[40] and Brazil.[15,37] In the prison population, we believe there is an indirect relation in which the absence of income due to unemployment would increase the probability of committing crimes with consequent imprisonment.

For these reasons, the AIDS incidence rate and unemployment rate should be considered in the adjustment of the association of exposure to prison and the TB incidence rate in other studies that investigate the factors associated with TB incidence.

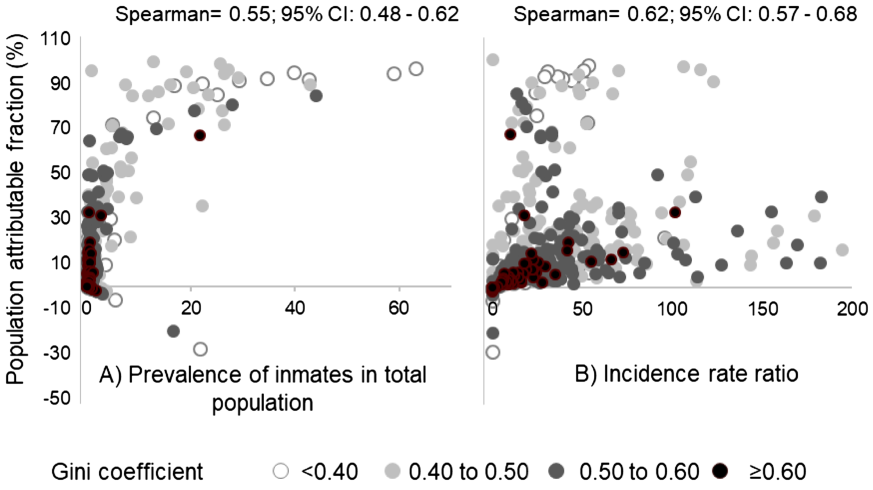

Figure 2. Distribution of the fraction of tuberculosis in the municipality population attributable to the exposure in prisons settings (PAF) according to the (**A**) prevalence of inmates in municipality population and (**B**) incidence rate ratio for prison. Brazil, 2013–2015. Truncated for incidence rate ratio <200.

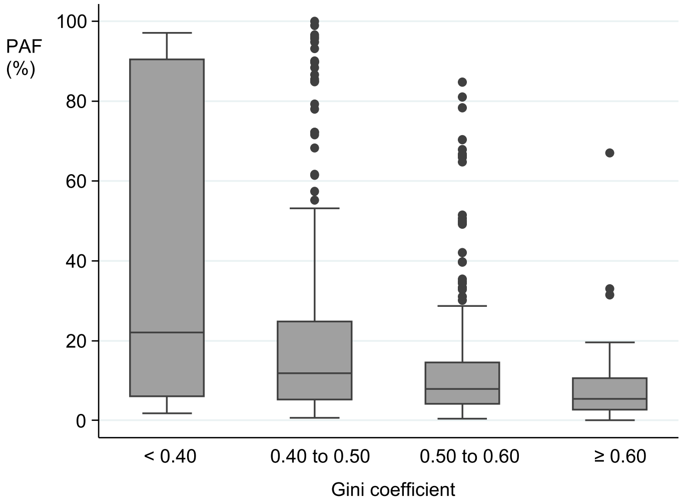

Figure 3. Distribution of the fraction of tuberculosis in the total municipality population attributable to the exposure in prisons settings (PAF) by Gini coefficient. Brazil, 2013–2015. Truncated for negative values of PAF.

Limitations

Despite Brazil consistently increased its case detection and notification,[16] TB underreporting is a potential limitation. However, one hypothesis is that underreporting may be either non-differential among municipalities or more frequent in municipalities with EIID. In both situations, the actual magnitude of the association between socio-economic factors and TB incidence in the non-exposed population would be higher than that observed in this study. If the risk of TB in prison was relatively stable, IRR changes would be attributable essentially to the baseline risk.

In addition, TB cases in the prison population were those detected during the period in which the patients were inside the prison. Prisoners that had TB after imprisonment were not considered in the calculations. The contacts of the prisoners who eventually developed TB were also not considered. If we consider that those patients could also be attributable to the exposure in prison, the actual PAF could be higher than estimated.

Moreover, this ecological study did not reveal the mechanisms involved in the increased risk of prisoners. In particular, individual variables not evaluated, such as sex, age, race and comorbidities, could explain this association at least partially. We included only the population ≥18 y of age, because data for the prison population stratified by age and sex in Brazilian municipalities were not available. However, it is valuable to estimate the association measures and PAF since these represent the overall impact of the exposures and their contribution is independent if they are explained in part by the demographic differences between the prison and non-prison populations.

Despite the limitations, our model included an important number of municipalities with prisons and high variability in the socio-economic determinants, which may be useful to extrapolate our results to other locations. In this sense, this work presented a broad panorama of the contribution of the prison population to the TB burden. Moreover, it demonstrated the impressive variability of this contribution, an aspect to be considered in the prioritization of this risk group.

Implications for public health and conclusion

Our study estimated the relative importance of prison exposure on TB incidence according to the socio-economic municipality situation, which could help TB programs to understand local TB epidemics and define control strategies. For example, municipalities with an equitable distribution of income would have a meaningful impact on the TB incidence rate with interventions focused on reducing the incarceration rate[41] or by improving the environmental conditions in prsions.[34] Considering that the burden of TB, particularly in low- and medium-burden countries, may be increasingly concentrated in high-risk subpopulations,[34] this could be an opportunity to concentrate key strategies in those populations, moving towards global progress in the control of the disease.

TB control in prison populations involves different and simultaneous approaches, such as screening of all individuals entering and exiting prisons, provision of isoniazid to those with latent TB at prison entry, improvement in the passive case detection rate, an annual active case detection campaign and improvement in poor ventilation and overcrowded cells.[9,34,42] Since prisons are considered 'institutional amplifiers'[42] or 'reservoirs'[43] of TB, prioritizing these approaches may have an impact on TB incidence not only in prison, but also in non-prison populations. A study found that focusing interventions on prisoners, who constitute $<0.3\%$ of the population in Brazil,[14] would reduce the total active TB incidence in the population by $>40\%$.[42] In our study, 10.22% of the TB cases would be potentially preventable if TB risk factors related with prison were eliminated from this population. This proportion was specifically higher in scenarios with a better profile of income distribution (PAF=50.06 for a Gini <0.40).

In contrast, in municipalities with EIID, strategies focused on mitigating the effects of socio-economic factors should also be prioritized, due to the substantial risk of the disease outside prisons. In these scenarios, intervention in the non-prison population, such as strengthening the coverage of primary health care[44] and focusing intervention on social protection[45] would be necessary to significantly impact the incidence of TB.

Conclusions

In conclusion, we identified a negative interaction between exposure to prison settings and EIID on the incidence of TB. This was explained by a positive association between EIID and the incidence of TB in the non-prison population. In these conditions, a low association measure may not imply TB control in prisons, but it indicates the necessity of additional social interventions to reduce vulnerabilities in the non-prison population.

Description of the process to obtain the data

Municipalities in Brazil have a unique code (código IBGE) that facilitates merging data and is available in all the data sources listed below. The socio-economic datasets from Brazil used in the current study are available from the "Departamento de Informática do SUS" repository (http://datasus.saude.gov.br/) and the Human Development Atlas repository (http://www.atlasbrasil.org.br/2013/en/consulta/). The datasets of TB indicators in Brazil are available by request from the Ministry of Health (https://esic.cgu.gov.br/sistema/site/index.aspx). The datasets of AIDS notification by municipalities in Brazil are available in the "Departamento de Informática do SUS" repository (http://datasus.saude.gov.br/). Information on the prison population is available from the Ministry of Justice repository (http://depen.gov.br/DEPEN/depen/sisdepen/infopen/infopen).

Authors' contributions: DMP and FADQ conceived and designed the study. DMP acquired data and wrote the first draft. FADQ critically reviewed the manuscript for important intellectual content. Both authors conducted the analyses, interpreted the data and read and approved the final manuscript.

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