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The yield of tuberculosis contact investigation in São Paulo, Brazil: a community-based cross-sectional study

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Abstract

The strategy of tuberculosis (TB) contact investigation is essential for enhancing disease detection. We conducted a cross-sectional study to evaluate the yield of contact investigation for new TB cases, estimate the prevalence of TB, and identify characteristics of index cases associated with infection among contacts of new cases notified between 2010 and 2020 in São Paulo, Brazil. Out of 186466 index TB cases, 131055 (70.3%) underwent contact investigation. A total of 652286 contacts were screened, of which 451704 (69.2%) were examined. Of these, 12243 were diagnosed with active TB (yield of 1.9%), resulting in a number needed to screen of 53 and a number needed to test of 37 to identify one new TB case. The weighted prevalence for the total contacts screened was 2.8% (95% confidence interval [CI]: 2.7%–2.9%), suggesting under-reporting of 6021 (95% CI: 5269–6673) cases. The likelihood of TB diagnosis was higher among contacts of cases identified through active case-finding, abnormal chest X-ray, pulmonary TB, or drug resistance, as well as among children, adults, women, individuals in socially vulnerable situations, and those with underlying clinical conditions. The study highlights significant TB underreporting among contacts, recommending strengthened contact investigation to promptly identify and treat new cases.

Introduction

Tuberculosis (TB) remains one of the leading cause of death from infectious diseases worldwide, posing a significant public health concern [1]. In 2022, there was a notable 28% increase in the global number of newly diagnosed cases compared to 2020 [1]. Nevertheless, the global targets set in 2018 regarding treatment, prevention, and funding have not been met, and efforts to reduce this burden remain insufficient [2]. To reverse this trend, it is crucial for each country to intensify the identification and proper treatment of TB cases, aiming to achieve the global goal of ending the epidemic by 2035 [1,3].

TB contact investigation is a crucial and cost-effective strategy [4], aimed at enhancing disease detection [5] and improving treatment outcome [6]. Its primary goal is to promptly identify and treat any secondary cases of the disease, as well as to detect contacts with latent TB infection (LTBI) eligible for preventive treatment [7]. Additionally, it plays a pivotal role in tracing the source case, particularly for children under 5 years old diagnosed with TB, facilitating the implementation of appropriate control measures [7]. The effectiveness of the investigation is assessed by its yield, which is the percentage of screened contacts found to have TB [3].

In a meta-analysis of 181 studies, the combined global prevalence of TB from contact investigations was 3.6%. This proportion was 5.0% in low-income countries, decreasing to 4.4% in middle-income countries and 1.8% in high-income countries [8]. In Brazil, a country with high middle-income status and a high TB burden, the incidence of TB among household contacts is estimated at 427.8 per 100000 person-years at risk, approximately 16 times the incidence in the general population [9], with prevalence potentially reaching 5.7% [10]. Since 2009, it has been recommended that all close contacts of a smear-positive pulmonary TB case, regardless of symptoms, age, and HIV status, undergo investigation for active TB or LTBI [11].

However, in 2023, only 53.9% of the identified contacts of laboratory-confirmed new pulmonary TB cases were examined [12]. Moreover, there is a lack of comprehensive information on the yield of this strategy in routine programmatic settings, as well as whether individual characteristics of index cases are associated with a higher likelihood of TB infection among contacts.

Understanding these factors can assist national programmes adapt their contact investigation strategies to improve their effectiveness and efficiency, especially in high-incidence settings [8,13]. Therefore, our aims were to evaluate the yield of community-based contact investigations for new TB cases, estimate disease prevalence among contacts, and identify which characteristics of index cases are associated to infection among contacts.

Methods

Study design and setting

A community-based cross-sectional study was conducted in the state of São Paulo, Brazil, from January 2010 to December 2020, using routinely collected data from the State Tuberculosis Control Program. São Paulo state is located in the Southeast region of Brazil and is the most populous and developed in the country. It leads the nation in TB cases, accounting for 24.5% of the total, with an estimated incidence above the national average of 42 cases per 100000 person-years [12].

Participants

The study included all contacts of new TB cases (index cases), defined as individuals who had never received TB treatment or had taken anti-TB medications for 1 month or less [1,11]. Our choice was based on the predominance of new cases (83%) and our consideration that the other cases belong to a distinct population, particularly regarding the exposure times between contacts and index cases, which consequently leads to a higher yield [13]. In this analysis, index cases were defined as patients diagnosed with TB according to national guidelines [11], and contacts were any individuals who had been exposed to an index case [7]. Screened contacts were those referred by index cases in the notification form. Examined contacts included all individuals who underwent clinical evaluation [7]. During this assessment, it was expected that all steps proposed by the contact investigation algorithm would be completed.

Data source

All information was obtained through the electronic Notification and Monitoring System for Tuberculosis Cases in the State of São Paulo (TBWEB). This system encompasses all TB cases reported by state residents and, in addition to the individual and clinical characteristics of index cases, includes three specific fields related to contact investigation, specifying the number of contacts screened, examined, and diagnosed with active TB per index patient. These recorded counts of contacts were used to determine the study outcomes.

Contact investigation procedure

Following the diagnosis of TB in the index case, regardless of clinical presentation, healthcare professionals conduct an in-person interview with the patient to gather information about all their contacts, including names, ages, and risk assessment, in order to prioritize clinical examination. Furthermore, they educate the patient on the importance of contact investigation. Subsequently, they request that contacts visit the designated health facility for evaluation or be contacted to schedule a visit, as needed [7,11].

Contacts are then assessed for the presence of persistent cough of any duration or other symptoms such as persistent fever, weight loss, anorexia, and night sweats, among others. Regardless of symptoms presented, a chest X-ray is requested. Contacts under 10 years old undergo tuberculin skin testing or interferon-gamma release assay (IFN-γ) to check for LTBI. Those over 10 years old who are capable of producing a sputum sample are investigated using sputum smear microscopy or GeneXpert MTB/RIF®. Cases positive on these tests are diagnosed with active TB and immediately start treatment, tailored to drug resistance patterns [11].

Contacts unable to produce sputum or those with negative sputum results but abnormal radiographic findings are referred for additional medical clinical evaluation. Also, asymptomatic contacts are screened for LTBI and, if necessary, referred for treatment [11]. However, we did not have access to this information; therefore, our assessment was limited to cases of active TB. It is important to note that all tests for the diagnosis and treatment of TB are fully covered by the Brazilian Unified Health System (SUS) [11]. Supplementary materials provide flowcharts for contact investigation based on the age of contacts (Supplementary Figures S1 and S2).

Variables

The primary outcome was the detection of TB among contacts of TB index patients. We interpreted 'positive yield' as the proportion of this outcome, i.e., the percentage of screened contacts diagnosed with active TB as a result of TB contact investigation strategy [7,13]. The following indicators were also assessed: proportion of index cases for which contacts were registered; proportion of screened contacts who were examined; number needed to screen (NNS), and number needed to test (NNT), to identify one new TB case [7].

Due to the absence of individual information on contacts, the independent variables considered in the analyses pertained to the characteristics of the index cases. These included sociodemographic information, health behaviours, medical history, and TB-related characteristics. A full description of all variables used in the study can be found in the Supplementary Table S1.

Statistical analyses

The characteristics of index cases and information about TB contact investigation were presented descriptively.

Predictive model for contact examination

We conducted various predictive modelling to estimate the likelihood of index cases having their contacts examined based on their characteristics. The final model was selected based on multiple criteria (Supplementary Figure S4 and Table S2). The zero-inflated Poisson (ZIP) regression model, with which we obtained a pseudo-R^2 of 51.6% (Supplementary Table S2), showed the best fit compared to the other models evaluated and was used to obtain probability estimates (Figure 1).

Prevalence and factors associated with infection among contacts

We calculated sampling weights as the inverse probability of contacts being examined using the predictions from the previous model. This approach allowed us to derive two prevalence estimates: one unweighted, representing the examined contacts, and one weighted, representing the screened contacts, both with their respective 95% confidence intervals (CIs). By comparing these two values, we estimated underreporting, indicating the likely number of undetected cases among all screened contacts. It is important to note that there is no record explaining why not all screened contacts were examined. Therefore, we assumed that unexamined contacts do not have a lower prevalence of TB, conditioning for the known characteristics of the index cases.

After, we also investigated factors associated with TB among contacts based on index case characteristics using multilevel mixed-

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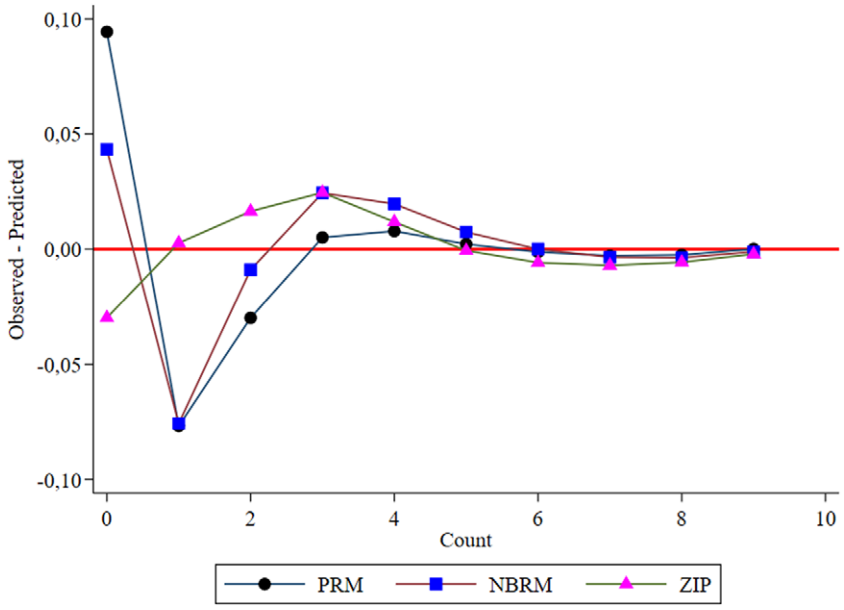

Figure 1. Comparisons among observed versus predicted probabilities among count models.
Abbreviations: PRM – Poisson Regression Model. NBRM – Negative Binomial Regression Model. ZIP – Zero-inflated Poisson.

effects Poisson regression model. Additionally, we incorporated random effects at the municipal level to address variability not explained by fixed predictors and employed robust standard error estimates. We obtained adjusted models both unweighted and weighted (based on the previously described weights), allowing estimates for examined contacts and the total screened contacts, respectively. Moreover, the weighting approach avoided introducing collider bias in the inference for screened contacts (Supplementary Figure S5).

The adjusted models were built using a hierarchical analysis, structured based on a conceptual framework (Supplementary Figure S6). This framework includes: first, temporal and geographical characteristics of index cases, as distal variables; second, sociodemographic and health characteristics, as intermediate I and II variables; and third, case detection strategies and clinical characteristics of index patients, as proximal variables. We interpreted the results in terms of prevalence ratio with their 95% CI, adopting a significance level of 5%. To address the missing values in the age variable, we performed simple data imputation (0.1% of index cases). For variables with more than 5% missing values, we included these cases as an additional category in the analysis.

We also estimated the intraclass correlation coefficient for each multilevel Poisson regression model to assess the proportion of total variation in TB prevalence among contacts attributable to differences between municipalities. Furthermore, we examined the effect of each municipality on TB prevalence among contacts and generated a caterpillar plot that organizes predicted proportions in ascending order along with their respective 95% CIs.

All analyses were performed using Stata version 16.1 (StataCorp LP, College Station, Texas, USA). This study was reported according to the recommendations of the RECORD statement.

Results

Characteristics of index cases

Between 1 January 2010 and 31 December 2020, a total of 186446 new TB cases were reported to the TBWEB system. Of these index cases, 70.7% were male (n = 131777) with a median age of 35 years (IQR: 25–49), and 84.6% (n = 157830) with pulmonary anatomical classification. Table 1 shows the remaining characteristics of the index cases and compares them with the screening of at least one contact.

The yield of contact investigation

Among index cases, 131055 (70.3%) had at least one contact registered in TBWEB, totalling 652286 contacts screened (5 per index case). The median number of contacts screened per index case was 3 (IQR: 2–5), ranging from 1 to 300. Regarding contact investigation, 451704 (69.2%) underwent examinations to detect the presence of the disease. The median number of contacts examined per index case was 3 (IQR: 2–5), ranging from 1 to 272. In total, 12243 new TB cases were diagnosed, representing an overall yield of contact investigation of 1.9% (Figure 2), resulting in an NNS of 53 and NNT of 37 (Table 1). The yield was higher among contacts of index cases with pulmonary TB (1.9%; NNS = 51) compared to those with extrapulmonary TB (1.2%; NNS = 86), and varied from 0.6% (NNS = 172) among contacts of index cases in correctional facilities to 12.1% (NNS = 8) among contacts of index cases under 5 years old (Table 1).

The prevalence of TB among contacts

We found that the unweighted prevalence among examined contacts was 2.7% (95% CI: 2.6%–2.8%). The weighted prevalence representing the total screened contacts was 2.8% (95% CI: 2.7%–2.9%), resulting in 18264 cases (95% CI: 17612–18916) among all screened contacts. These results suggest that 6021 cases (95% CI: 5269–6673) of undetected infections among contacts referred by index cases. Table 2 shows additional prevalence values disaggregated according to the characteristics of the index cases.

Factors associated with TB diagnosis among contacts

Index patients from the metropolitan areas of Campinas, Baixada Santista, Vale do Paraíba e Litoral Norte, and Sorocaba were associated with a higher likelihood of TB diagnosis among their

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Table 1. Characteristics of tuberculosis index cases, yield of tuberculosis contact investigations, number needed to screen, and number needed to treat in São Paulo, Brazil, 2010–2020

	Index cases of TB		Contact investigation					
	Overall	with at least one registered contact	Screened	Examined	Active TB	Yield		
Characteristics of the index cases	*N*	*N* (%)	*N*	*N*	*N*	%	NNS	NNT
Total	**186,446**	**131,055 (70.3)**	**652,286**	**451,704**	**12,243**	**1.9**	**53**	**37**
Year of diagnose								
2010	15,914	11,468 (72.1)	53,927	41,284	1,278	2.4	42	32
2011	16,542	12,096 (73.1)	57,861	43,137	1,396	2.4	41	31
2012	16,122	11,803 (73.2)	58,779	42,577	1,339	2.3	44	32
2013	16,654	12,057 (72.4)	61,112	42,818	1,141	1.9	54	38
2014	16,517	11,627 (70.4)	61,294	42,446	1,010	1.6	61	42
2015	17,019	11,752 (69.0)	58,044	37,806	1,081	1.9	54	35
2016	16,928	11,689 (69.0)	59,497	39,156	919	1.5	65	43
2017	18,336	12,650 (69.0)	67,667	46,244	1,159	1.7	58	40
2018	18,454	12,985 (70.4)	62,136	42,701	1,062	1.7	59	40
2019	18,064	12,485 (69.1)	60,048	42,285	1,046	1.7	57	40
2020	15,916	10,443 (65.6)	50,891	31,250	812	1.6	63	38
Sex								
Male	131,777	88,872 (67.4)	493,790	347,660	7,437	1.5	103	72
Female	54,689	42,183 (77.1)	158,496	104,044	4,806	3.0	21	14
Age group (years)								
< 5	2,290	1,733 (75.7)	7,860	5,590	954	12.1	8	6
5–14	3,579	2,919 (81.6)	13,680	9,833	1,474	10.8	9	7
15–19	10,929	9,090 (83.2)	43,365	28,609	1,271	2.9	34	22
20–59	147,624	102,474 (69.4)	537,110	373,937	7,941	1.5	68	47
≥ 60	21,777	14,704 (67.5)	50,271	33,735	657	1.3	77	51
Self-reported race or ethnicity								
White	80,153	56,895 (71.0)	270,320	191,684	4,421	1.6	61	43
Black	19,442	13,344 (68.6)	66,705	45,202	1,314	2.0	51	34
Brown or mixed	63,624	45,813 (72.0)	246,536	169,255	5,142	2.1	48	33
Asian	1,607	1,141 (71.0)	4,360	2,827	91	2.1	48	31
Indigenous	767	611 (79.7)	3,751	2,922	180	4.8	21	16
Unknown	20,873	13,251 (63.5)	60,614	39,814	1,095	1.8	55	36
Education (years of study)								
Illiterate	5,785	4,209 (72.8)	20,533	15,116	1,112	5.4	18	14
1–3	14,614	10,755 (73.6)	52,046	37,050	1,255	2.4	41	30
4–7	50,403	36,135 (71.7)	204,110	145,894	3,555	1.7	57	41
8–11	55,288	42,177 (76.3)	203,838	140,795	3,479	1.7	59	40
≥12	17,068	12,875 (75.4)	46,012	29,827	712	1.5	65	42
Unknown	43,308	24,904 (57.5)	125,657	83,022	2,130	1.7	59	39
Country of birth								
Brazil	168,718	119,110 (70.6)	597,154	414,695	10,870	1.8	55	38
Other country	1,288	887 (68.9)	3,933	2,274	196	5.0	20	12
Unknown	16,460	11,058 (67.2)	51,199	34,735	1,177	2.3	43	30

(*Continued*)

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Table 1. (*Continued*)

	Index cases of TB		Contact investigation					
	Overall	with at least one registered contact	Screened	Examined	Active TB	Yield		
Characteristics of the index cases	*N*	*N* (%)	*N*	*N*	*N*	%	NNS	NNT
Homeless								
No	6,063	928 (15.1)	4,553	2,873	117	2.6	39	25
Yes	180,403	130,127 (72.1)	647,733	448,831	12,126	1.9	53	37
Incarcerated								
No	164,109	118,104 (72.0)	434,960	285,143	10,978	2.5	40	26
Yes	22,357	12,951 (57.9)	217,326	166,561	1,265	0.6	172	132
Metropolitan area of residence								
São Paulo	96,975	70,067 (72.2)	258,744	156,422	7,147	2.8	36	22
Ribeirão Preto	3,395	1,943 (57.2)	7,570	5,234	306	4.0	25	17
Sorocaba	5,342	3,538 (66.2)	12,492	7,412	228	1.8	55	33
Campinas	10,606	7,718 (72.8)	30,934	22,066	777	2.5	40	28
Vale do Paraíba e Litoral Norte	7,485	5,129 (68.5)	19,910	14,208	406	2.0	49	35
Baixa Santista	16,333	11,618 (71.1)	39,779	24,659	791	2.0	50	31
Others	46,330	31,042 (23.7)	282,857	221,703	2,588	0.9	109	87
Case detection strategies								
ACF in institutions	9,463	5,271 (55.7)	90,069	69,069	621	0.7	145	111
Community-based ACF	4,132	3,314 (80.2)	13,538	9,161	366	2.7	37	25
Contact investigation	6,097	4,938 (81.0)	33,551	26,854	3,777	11.3	9	7
PCF in hospital	33,699	20,981 (62.3)	315,293	218,752	4,630	1.2	68	47
PCF in emergence room	38,224	27,667 (72.4)	77,754	49,642	935	1.2	83	53
PCF in outpatient clinics	89,111	65,911 (74.0)	106,529	67,296	1,686	1.6	63	40
Post-mortem	2,099	499 (24.8)	2,143	1,379	36	1.7	60	38
Unknown	3,731	2,474 (66.3)	13,409	9,551	192	1.4	70	49
Smoking								
No	156,978	111,879 (71.3)	543,251	381,536	10,750	2.0	51	35
Yes	29,488	19,176 (65.0)	109,035	70,168	1,493	1.4	73	47
Alcohol								
No	156,780	110,216 (70.3)	571,260	399,170	10,934	1.9	52	37
Yes	29,686	20,839 (70.2)	81,026	52,534	1,309	1.6	62	40
Drug user								
No	161,004	114,410 (71.1)	555,198	389,955	10,798	1.9	51	36
Yes	25,462	16,645 (65.4)	97,088	61,749	1,445	1.5	67	43
Diabetes mellitus								
No	174,722	122,060 (69.9)	619,735	430,102	11,847	1.9	52	36
Yes	11,744	8,995 (76.6)	32,551	21,602	396	1.2	82	56
Mental disorder								
No	183,587	129,078 (70.3)	641,712	444,396	12,042	1.9	53	37
Yes	2,879	1,977 (68.7)	10,574	7,308	201	1.9	53	36
Other immunosuppression								
No	184,219	129,659 (70.4)	647,553	448,734	12,183	1.9	53	37
Yes	2,247	1,396 (62.1)	4,733	2,970	60	1.3	79	50

(*Continued*)

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Table 1. (*Continued*)

	Index cases of TB		Contact investigation					
	Overall	with at least one registered contact	Screened	Examined	Active TB	Yield		
Characteristics of the index cases	*N*	*N* (%)	*N*	*N*	*N*	%	NNS	NNT
No comorbidities								
No	114,783	75,008 (65.4)	352,563	230,485	5,556	1.6	63	41
Yes	71,683	56,047 (78.2)	299,723	221,219	6,687	2.2	45	33
HIV status								
Negative	147,483	110,628 (75.0)	558,867	398,079	10,448	1.9	53	38
Positive	16,151	7,585 (47.0)	31,280	18,403	373	1.2	84	49
Unknown	22,832	12,842 (56.2)	62,139	35,222	1,422	2.3	44	25
Chest X-ray								
Not done	47,361	30,016 (63.4)	254,638	186,901	2,699	1.1	94	7
Normal	11,376	7,278 (64.0)	27,727	18,653	533	1.9	52	35
Abnormal	127,729	93,761 (73.4)	369,921	246,150	9,011	2.4	41	27
Anatomical classification								
Extrapulmonary tuberculosis	28,636	17,633 (61.6)	58,013	35,677	678	1.2	86	53
Pulmonary tuberculosis	157,830	113,422 (71.9)	594,273	416,027	11,565	1.9	51	36
Microbiological status								
Negative	34,565	23,679 (68.5)	90,268	60,440	2,159	2.4	42	28
Positive	127,015	91,068 (71.7)	500,101	353,414	7,622	1.5	66	46
Unknown	24,886	16,308 (65.5)	61,917	37,850	2,462	4.0	25	15
Drug-resistant tuberculosis								
No	184,630	129,773 (70.3)	644,056	446,209	12,124	1.9	53	37
Yes	1,836	1,282 (69.8)	8,230	5,495	119	1.4	69	46

Note: Yield was defined as the total number of active TB cases divided by the total number of contacts screened. NNS was expressed as the total number of contacts screened divided by the number of active TB cases needed to detect one new TB case. NNT was expressed as the total number of contacts examined divided by the number of active TB cases needed to detect one new TB case.
Abbreviations: NNS – number needed to screen. NNT – number needed to test. PCF – passive case-finding. ACF – active case-finding.

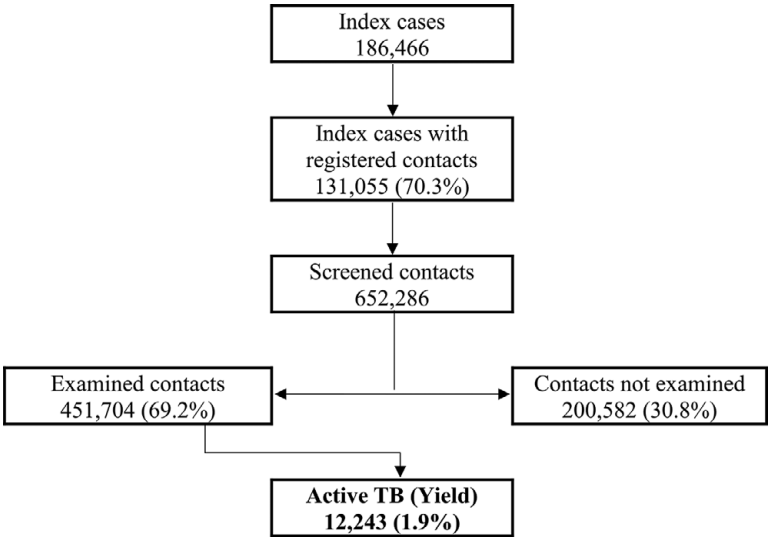

Figure 2. Flowchart of screening and yield from tuberculosis contact investigation in the State of São Paulo, Brazil, 2010–2020.

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Table 2. Prevalences and multilevel Poisson regression analysis adjusted for characteristics of tuberculosis index cases associated with the presence of tuberculosis diagnosis among their contacts. São Paulo, Brazil, 2010–2020

	Prevalence of active TB		Poisson with random effect	
	Unweighted	Weighted*	Model 1	Model 2
Variables	%	%	Adjusted PR (95% CI)	Adjusted PR (95% CI)
Overall	2.7	2.8	-	-
Individual level				
Distal variables[a]				
Metropolitan area of residence				
Others	1.2	1.1	Reference	Reference
Baixa Santista	3.2	3.2	**1.74 (1.22–2.47)**	**1.89 (1.34–2.66)**
Campinas	3.1	3.4	**1.40 (1.05–1.83)**	**1.39 (1.04–1.85)**
Ribeirão Preto	5.8	5.6	1.19 (0.70–2.02)	1.08 (0.61–1.90)
São Paulo	4.6	4.3	1.12 (0.90–1.37)	1.14 (0.92–1.40)
Sorocaba	3.1	3.3	1.42 (0.99–2.03)	**1.45 (1.02–2.19)**
Vale do Paraíba e Litoral Norte	2.9	2.8	**1.39 (1.03–1.85)**	**1.45 (1.08–1.95)**
Intermediate variables I[b]				
Sex				
Male	2.1	2.2	Reference	Reference
Female	4.6	4.5	**1.27 (1.19–1.35)**	**1.27 (1.19–1.34)**
Age group (years)				
≥ 60	1.9	1.9	Reference	Reference
20–59	2.1	2.2	**1.43 (1.32–1.55)**	**1.44 (1.33–1.56)**
15–19	4.3	4.3	**2.21 (2.02–2.42)**	**2.22 (2.03–2.43)**
5–14	15.0	14.6	**4.75 (4.26–5.29)**	**4.77 (4.23–5.34)**
<5	17.1	16.6	**5.31 (4.51–6.24)**	**5.37 (4.56–6.34)**
Self-reported race or ethnicity				
White	2.3	2.3	Reference	Reference
Black	2.9	2.9	**1.18 (1.08–1.27)**	**1.17 (1.09–1.26)**
Brown or mixed	3.0	3.1	**1.20 (1.12–1.29)**	**1.21 (1.12–1.30)**
Asian	3.2	3.0	1.09 (0.80–1.47)	1.06 (0.78–1.44)
Indigenous	6.2	5.7	1.21 (0.95–1.54)	1.22 (0.98–1.52)
Unknown	2.8	2.8	1.08 (0.95–1.23)	1.09 (0.96–1.24)
Country of birth				
Brazil	2.6	2.7	Reference	Reference
Other country	8.6	8.0	**1.70 (1.51–1.88)**	**1.71 (1.56–1.87)**
Unknown	3.4	3.3	0.98 (0.90–1.06)	0.97 (0.89–1.05)
Intermediate variables II[b]				
Education (years of study)				
≥12	2.4	2.4	Reference	Reference
8–11	2.5	2.5	**1.25 (1.12–1.36)**	**1.26 (1.16–1.36)**
4–7	2.4	2.5	**1.36 (1.23–1.48)**	**1.37 (1.26–1.49)**
1–3	3.4	3.4	**1.55 (1.24–1.77)**	**1.54 (1.40–1.73)**
Illiterate	7.4	7.3	**1.64 (1.46–1.84)**	**1.63 (1.47–1.83)**
Unknown	2.6	2.6	**1.30 (1.18–1.43)**	**1.29 (1.16–1.43)**

(*Continued*)

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Table 2. (*Continued*)

	Prevalence of active TB		Poisson with random effect	
	Unweighted	Weighted*	Model 1	Model 2
Variables	%	%	Adjusted PR (95% CI)	Adjusted PR (95% CI)
Homeless	4.1	4.0	**1.47 (1.27–1.71)**	**1.45 (1.26–1.67)**
HIV status				
Negative	2.6	2.6	Reference	Reference
Positive	2.0	2.1	**0.83 (0.71–0.99)**	**0.85 (0.72–0.98)**
Unknown	4.0	4.0	**1.21 (1.12–1.31)**	**1.20 (1.10–1.30)**
Smoking	2.1	2.2	**1.10 (1.02–1.18)**	**1.10 (1.01–1.18)**
Drug user	2.3	2.4	**1.34 (1.26–1.45)**	**1.36 (1.28–1.46)**
Diabetes mellitus	1.8	1.8	**0.77 (0.68–0.86)**	**0.76 (0.68–0.86)**
Other immunosuppression	2.0	2.1	**0.61 (0.48–0.77)**	**0.66 (0.52–0.82)**
Proximal variables[c]				
Case detection strategies				
PCF in outpatient clinics	2.1	2.3	Reference	Reference
PCF in hospital	1.9	1.9	**0.77 (0.71–0.84)**	**0.76 (0.69–0.84)**
PCF in emergence room	2.5	2.5	**0.87 (0.77–0.98)**	**0.86 (0.76–0.96)**
Post-mortem	2.6	2.7	0.91 (0.64–1.27)	0.85 (0.67–1.18)
ACF in institutions	0.9	0.9	**1.19 (1.11–1.29)**	**1.16 (1.08–1.23)**
Community-based ACF	4.0	4.1	**1.25 (1.14–1.37)**	**1.23 (1.14–1.33)**
Contact investigation	14.1	14.8	**4.62 (4.32–4.94)**	**4.43 (4.15–4.74)**
Unknown	2.0	2.2	1.15 (0.99–1.33)	1.13 (0.98–1.31)
Chest X-ray				
Not done	1.4	1.5	1.07 (0.98–1.17)	1.07 (0.97–1.18)
Normal	2.9	2.8	Reference	Reference
Abnormal	3.7	3.6	**1.11 (1.03–1.19)**	**1.12 (1.03–1.21)**
Anatomical classification				
Extrapulmonary tuberculosis	1.9	1.9	Reference	Reference
Pulmonary tuberculosis	2.8	2.8	**1.73 (1.61–1.86)**	**1.76 (1.65–1.89)**
Drug-resistant tuberculosis				
No	2.7	2.8	Reference	Reference
Yes	2.2	2.2	**1.19 (1.01–1.41)**	**1.22 (1.03–1.44)**
Municipal level				
Variance (SE)	-	-	0.231 (0.355)	0.307 (0.042)
% ICC (95% CI)	-	-	6.6 (5.0–8.7)	8.6 (6.7–10.9)

Note: Model 1: unweighted, representing examined contacts. Model 2: weighted, representing the total screened. Bold values indicate statistically significant associations.
Abbreviations: PR – prevalence ratio. 95% CI – 95% confidence interval. PCF – passive case-finding. ACF – active case-finding. SE – standard error. ICC – intraclass correlation coefficient.
*Prevalence weighted by the inverse probability of being examined.
[a]Distal model, RP adjusted for years of diagnose and metropolitan area of residence.
[b]Intermediate model, PR adjusted for sex, age group, self-reported or race or ethnicity, country of birth, education, homelessness, HIV status and comorbidities, plus distal variable.
[c]Proximal model, RP adjusted for case detection strategies, chest X-ray, anatomical classification and drug-resistant tuberculosis, plus distal and intermediate variables.

contacts compared to those in other metropolitan areas. Similarly, index cases of Black or Brown races/ethnicities showed a greater probability of TB compared to White race/ethnicity patients. This trend was also observed among contacts of female index patients, foreigners, and individuals experiencing homelessness. However, an inverse relationship was noted between younger age and lower years of schooling among index patients and the likelihood of TB diagnosis among their contacts, compared to index patients aged 60 years and older and those with more than 12 years of education, respectively (Table 2).

Additionally, index cases who were smokers, illicit drug users, had a pulmonary TB diagnosis, or drug resistance also showed an

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increased probability of TB diagnosis among their contacts compared to index patients without these characteristics. Furthermore, index cases with unknown HIV status, identified through active case-finding strategies, and with abnormal chest X-rays were associated with a higher probability of TB diagnosis among their contacts, compared to HIV-negative index patients, identified through passive case-finding, and with normal chest X-rays, respectively (Table 2).

Examining the effect of municipalities on TB prevalence among contacts

We found that 6.6% (95% CI: 5.0%–8.7%) and 8.6% (95% CI: 6.7%–10.9%) of the variation in TB prevalence among examined and screened contacts, respectively, was attributed to variation between municipalities (Table 2). For 21 municipalities, the 95% CIs were below the zero line, indicating lower predicted TB prevalence among contacts compared to the average. In contrast, 43 municipalities had 95% CIs above the zero line, suggesting higher TB prevalence among contacts than the average. For 90% of the municipalities included, it was not possible to distinguish from the overall average due to overlapping 95% CIs with the zero line (Figure 3). For more information, please consult Supplementary Table S3.

Discussion

In this study, we evaluated the yield of TB contact investigation strategies among index cases in the state of São Paulo, Brazil, using available surveillance data. We estimated the prevalence of TB among contacts and identified the characteristics of index cases associated with active TB diagnosed among their contacts. The yield was 1.9% among screened contacts, increasing to 2.7% among those examined. These results align with estimates from other studies in Brazil across different populations, ranging from 1.9% to 3.0% [14,15], although they remain slightly lower than the global range of 2.87%–3.60% reported in previous studies [3,5,8,16]. Nevertheless, these numbers are comparable to those observed in other countries in the Americas (2.68%) [3] and in similar income and incidence settings (2.22% and 1.9%, respectively) [3,8]. They are also consistent with the yield reported in another study that used data from national TB surveillance program data (1.8%) [17]. Additionally, our findings reveal that the weighted prevalence inferred for all screened contacts was 2.8% (95% CI: 2.7%–2.9%), representing underreporting of nearly one-third of all cases among contacts. This result aligns with previous studies that employed different approaches to determine underreporting [18].

Our study shows that, on average, nine contacts are diagnosed with TB for every 100 index cases screened. This estimate likely underestimates the true proportion of cases per index patient, as 30% of them did not report any contacts. However, it is crucial to note that this non-screening rate is lower than that found in other high TB-burden countries in Africa, Asia, and the Middle East [17]. Another significant finding is the proportion of contacts that were actually examined, which accounts for nearly 70% of the total contacts screened. We considered that this gap between screened and examined contacts may explain the lower yield compared with previous studies.

It is essential to emphasize that the issue of underdiagnosis of the disease requires further research, especially due to previous findings that highlighted the stigma associated with TB and HIV as a significant barrier to contact investigation [19,20]. Furthermore, other studies indicate that difficulties in reporting contacts by index cases may be attributed not only to stigma but also to the complexity arising from the number and identity of potentially exposed contacts, the strategies used for contact tracing, limited knowledge about the disease among contacts, challenges in accessing health services, and inadequate follow-up by health teams after contact identification, among others [21,22]. These factors, whether alone or in combination, may contribute to a scenario where TB cases among contacts are not promptly diagnosed and treated, thereby increasing disease transmission [20].

This result further underscores the need to ensure the completion of the entire contact tracing cascade for all eligible index cases, thereby avoiding selection bias towards individuals who self-identify as symptomatic [23]. This process is crucial, particularly in resource-limited settings where contacts are encouraged to seek medical assistance only when symptoms appear [16]. Previous evidence supports this finding, demonstrating that locations testing all contacts, regardless of symptoms, achieved a more significant detection of TB cases compared to those applying more restrictive

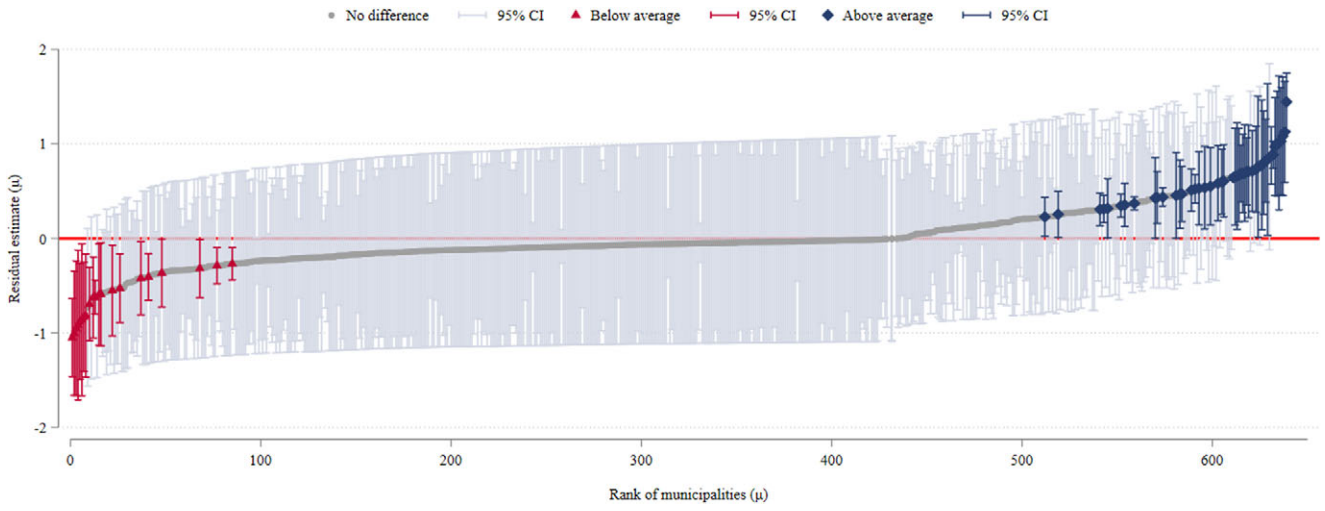

Figure 3. Caterpillar plot showing the effect of municipalities on tuberculosis prevalence among contacts and their respective 95% confidence intervals ($n = 639$). São Paulo, Brazil, 2010–2020.

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criteria [7,24]. Moreover, integrating laboratory tests into contact tracing activities can be a valuable investment, given the limitations of relying solely on symptoms to guide TB case screening [16,25]. It is also crucial to highlight the importance of identifying and initiating early treatment for LTBI among eligible contacts of index cases, which helps prevent future reactivations of TB [26]. Unfortunately, these data on LTBI were not available for analysis in our study.

In this investigation, on average, 53 contacts need to be screened and 37 examined to identify a case of active TB, a result similar to other studies [17,27,28]. This implies conducting approximately eleven home visits, considering the average number of contacts per index case (53/5), which can be a significant expenditure of resources and a burden on healthcare professionals, depending on the location. Notably, we observed that this number is significantly lower in certain groups, which supports World Health Organization (WHO) and national guidelines to target screening towards specific groups at higher risk of the disease [7,11]. This targeted approach suggests that additional screening efforts in these groups would be an effective way to enhance the detection and control of TB [16,27].

Our analyses indicated that contacts of index cases with drug resistance were more likely to be diagnosed with TB compared to contacts of drug-susceptible index cases [29], although the literature remains inconsistent [30]. We also observed that contacts of index cases with pulmonary TB and abnormalities on chest X-rays were more likely to be diagnosed with TB compared to cases with extrapulmonary TB and normal chest X-rays. The high risk of infection in contacts of patients with these characteristics is plausible because pulmonary lesions release large quantities of bacilli, including drug-resistant strains, which significantly enhances the transmission of the disease to close contacts [9,14,29]. In addition, the strategy used to identify the TB index case was associated with the presence of the disease among contacts. This finding add to others studies that emphasize the effectiveness of active case-finding strategies in early detection of new cases and LTBI [5,31], and in reducing mortality and unfavourable treatment outcomes [6].

Studies have shown that smoking, illicit drug use, and other immunosuppressive conditions are known risk factors for TB infection, due to their negative impact on lung function and the immune system's ability to fight infections [32,33]. We also identified an association between TB index cases with such characteristics and the disease prevalence among their contacts. This relationship is likely a result of increased exposure of contacts to infectious droplets from index cases, due to the sharing of objects in close environments with low air circulation, no ultraviolet light, and inadequate protection [34,35]. We also noted an intriguing finding, contacts of TB index cases with diabetes mellitus (DM) showed a lower likelihood of TB diagnosis compared to those without DM, which concurs with previous studies [30]. However, this result contrasts with two other studies conducted in Brazil [34,36]. This discrepancy reveals the complexity of the relationship between DM and TB and suggests the need for more comprehensive cohort studies to clarify these associations between TB index cases and their contacts.

Despite strong recommendations in national [11] and international guidelines [7] for screening and testing all contacts of people living with HIV, less than half of them had their contacts screened in our study, with only 58.8% (n = 18403) undergoing examination. These findings indicate the urgency of implementing tailored strategies to ensure an inclusive and effective approach in controlling TB and HIV among their contacts. The association identified in our study between sex and TB diagnosis can be attributed to the central role women play in family activities, particularly in looking after others. This leads to extended exposure time for their contacts [37], reflecting a pattern observed in other studies [9].

Our study shows a higher prevalence of TB among contacts of index patients belonging to groups with historical characteristics of social vulnerability, such as those with low education, black and mixed-race ethnicity, homelessness, foreigners, and residents in overcrowded populated areas. These groups, likely due to their precarious housing conditions, restricted access to healthcare services, low income, and unemployment, are more likely to come into contact with patients with active TB, thereby facilitating the spread of the disease among contacts [38,39].

Finally, we found an inverse association between the age of index cases and the prevalence of TB among their contacts, consistent with other studies on the subject [9,40]. This finding is understandable, as children are prioritized in contact tracing policies due to the high likelihood of disease transmission occurring within the family environment [11]. Therefore, identifying index patients under 5 years old might trigger more intensive case-finding efforts within healthcare services [9]. Hence, we suggest that improving contact investigation across all age groups of index patients could have a significant impact on TB prevention and treatment within the state and the country as a whole.

Limitations and strengths

Our study also had some limitations. The unavailability of data on the characteristics of contacts, including their relationship with the index case and genotypic matching, limited our ability to thoroughly assess whether these factors could influence the likelihood of being examined and the potential determinants of TB among them. This information is not routinely recorded in TBWEB. In addition, we assumed that the lack of examination for some contacts was not related to variables other than those assessed in the index cases. We cannot rule out the possibility of underreporting of contacts by index cases, which may suggest that our underreporting estimates are conservative (i.e., may be higher). Therefore, it is essential to enhance surveillance and recording of contacts in TBWEB to obtain more accurate prevalence estimates in future studies. Due to the cross-sectional design of the study, we were unable to establish the time interval between the initial TB report of the index case and the development of the disease among their contacts. This limitation prevents us from determining whether the cases are co-prevalent or incident. However, we believe they are likely co-prevalent, given that the study focused exclusively on new TB cases and employed an investigation algorithm that typically prioritizes recent cases to identify active disease outbreaks. Moreover, we cannot confirm whether the contacts acquired TB through direct transmission from the index patient, external exposure, or reactivation of LTBI. These considerations underscore the importance of including such information in future longitudinal studies to better elucidate transmission patterns, disease risk under different circumstances, and the cost-effectiveness of contact investigations. This would provide more robust evidence. Furthermore, such studies could determine whether conducting contact screening for all cases would increase yield compared to current symptom-based recommendations, which focus on individuals with bacteriologically confirmed pulmonary TB, children aged 5 years or younger, and people living with HIV.

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Despite these limitations, the study has several strengths that deserve highlighting. First, the data for this evaluation were routinely collected by the state TB control programme and, therefore, accurately reflect programmatic conditions in low- and middle-income settings with a high TB burden. Consequently, our results are likely generalizable to similar settings where the WHO currently recommends contact investigations. Second, our analysis contributes to a growing body of literature that assesses the effectiveness of TB contact investigation strategies and their performance across different groups and predisposing factors. Third, we employed weighting strategies to ensure the representativeness of the number of contacts screened in the prevalence results, allowing us to estimate the probable number of underreported cases. Fourth, given that the weights were derived from a well-performing model, we believe this contributed to generating more accurate estimates for the entire screened population, thereby mitigating potential selection biases related to factors influencing the examination of contacts. Finally, the study's strength lies in the large number of contacts screened and examined compared to previous studies.

Consequently, we recommend strengthening and expanding contact investigations for all TB index cases to facilitate early detection and appropriate treatment of new cases. On the other hand, in resource-limited settings, priority should be given to investigating contacts of specific index cases, such as those in socially vulnerable groups, including women, children, and cases indicating more severe disease. These findings have significant implications for public health policies related to TB control, not only in the state of São Paulo but also in other regions with similar contexts.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/S0950268824001675.

Data availability statement. Due to the ethical reason, data sharing is not applicable.

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Author contribution. JMNS and FADQ conceptualized the study. JMNS conducted data collection, organization, and analysis. FADQ provided supervision and contributed to the planning of the analyses. All authors participated in interpreting the results. JMNS drafted the initial version of the manuscript. FADQ made substantial contributions to the revision, and both JMNS and FADQ reviewed and approved the final version.

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Competing interest. The authors declare none.

Ethical standard. The study was approved by the Research Ethics Committee of the School of Public Health at the University of São Paulo (protocol number: 4285870).

References

[1] **World Health Organization**. (2023) *Global Tuberculosis Report 2023*. Geneva, Switzerland: World Health Organization.

[2] **Fukunaga R**, et al. (2021) Epidemiology of tuberculosis and progress toward Meeting Global Targets — Worldwide, 2019. *MMWR. Morbidity and Mortality Weekly Report* **70**,427–430.

[3] **Velleca M**, et al. (2021) The yield of tuberculosis contact investigation in low- and middle-income settings: a systematic review and meta-analysis. *BMC Infectious Diseases* **21**, 1011.

[4] **Lung T**, et al. (2019) Household contact investigation for the detection of tuberculosis in Vietnam: economic evaluation of a cluster-randomised trial. *Lancet Global Health* **7**, e376–e384.

[5] **Fox GJ**, et al. (2013) Contact investigation for tuberculosis: a systematic review and meta-analysis. *European Respiratory Journal* **41**, 140–156.

[6] **da Silva JMN**, **Diaz-Quijano FA**. (2024) Effect of case detection strategies on the prognosis of tuberculosis patients in the state of São Paulo, Brazil, 2010–19: A retrospective cohort study. *Trop Med Int Health*; https://doi.org/10.1111/tmi.14074.

[7] **World Health Organization**. (2021) *WHO Consolidated Guidelines on Tuberculosis. Module 2: Screening – Systematic Screening for Tuberculosis Disease*. Geneva, Switzerland: World Health Organization.

[8] **Velen K**, et al. (2021) The effectiveness of contact investigation among contacts of tuberculosis patients: a systematic review and meta-analysis. *European Respiratory Journal* **58**, 2100266.

[9] **Pinto PFPS**, et al. (2024) Incidence and risk factors of tuberculosis among 420 854 household contacts of patients with tuberculosis in the 100 Million Brazilian Cohort (2004–18): a cohort study. *The Lancet Infectious Diseases* **24**, 46–56.

[10] **Acuña-Villaorduña C**, et al. (2018) Cough-aerosol cultures of Mycobacterium tuberculosis in the prediction of outcomes after exposure. A household contact study in Brazil. *PLOS ONE* **13**, e0206384.

[11] **Ministério da Saúde do Brasil. Secretaria de Vigilância em Saúde. Departamento de Vigilância das Doenças Transmissíveis**. (2019) *Manual recomendações para o controle da tuberculose*, 2nd Edn. Brasília, Distrito Federal: Ministério da Saúde.

[12] **Ministério da Saúde do Brasil. Secretaria de Vigilância em Saúde e Ambiente**. (2024) *Boletim Epidemiológico – Tuberculose 2024*. Brasília, Distrito Federal: Ministério da Saúde.

[13] **Baluku JB**, et al. (2022) Tuberculosis contact tracing yield and associated factors in Uganda. *BMC Pulmonary Medicine* **22**, 64.

[14] **Cubillos-Angulo JM**, et al. (2019) Polymorphisms in TLR4 and TNFA and risk of mycobacterium tuberculosis infection and development of active disease in contacts of tuberculosis cases in Brazil: a prospective cohort study. *Clinical Infectious Diseases* **69**, 1027–1035.

[15] **Cailleaux-Cezar M**, et al. (2009) Tuberculosis incidence among contacts of active pulmonary tuberculosis. *The International Journal of Tuberculosis and Lung Disease* **13**, 190–195.

[16] **Deya RW**, et al. (2022) Yield and coverage of active case finding interventions for tuberculosis control: a systematic review and meta-analysis. *Tuberculosis Research and Treatment* **2022**, 1–12.

[17] **Blok L**, et al. (2015) Comparative meta-analysis of tuberculosis contact investigation interventions in eleven high burden countries. *PLOS ONE* **10**, e0119822.

[18] **de Oliveira GP**, et al. (2012) Uso do sistema de informação sobre mortalidade para identificar subnotificação de casos de tuberculose no Brasil. *Revista Brasileira de Epidemiologia* **15**, 468–477.

[19] **Faccini M**, et al. (2015) Tuberculosis-related stigma leading to an incomplete contact investigation in a low-incidence country. *Epidemiology and Infection* **143**, 2841–2848.

[20] **Kolte IV**, et al. (2020) The contribution of stigma to the transmission and treatment of tuberculosis in a hyperendemic indigenous population in Brazil. *PLOS ONE* **15**, e0243988.

[21] **Fenta MD**, et al. (2023) Facilitators and barriers to tuberculosis active case findings in low- and middle-income countries: a systematic review of qualitative research. *BMC Infectious Diseases* **23**, 515.

[22] **Ayakaka I**, et al. (2017) Identifying barriers to and facilitators of tuberculosis contact investigation in Kampala, Uganda: a behavioral approach. *Implementation Science* **12**, 33.

[23] **Subbaraman R**, et al. (2020) Closing gaps in the tuberculosis care cascade: an action-oriented research agenda. *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases* **19**, 100144.

[24] **van't Hoog A**, et al. (2022) Symptom- and chest-radiography screening for active pulmonary tuberculosis in HIV-negative adults and adults with unknown HIV status. *The Cochrane Database of Systematic Reviews* **3**, CD010890.

[25] **Habte D**, et al. (2016) The additional yield of GeneXpert MTB/RIF test in the diagnosis of pulmonary tuberculosis among household contacts of smear positive TB cases. *The International Journal of Infectious Diseases* **49**, 179–184.
[26] **Souza AB**, et al. (2021) Determinants of losses in the latent tuberculosis infection cascade of care in Brazil. *BMJ Global Health* **6**, e005969.
[27] **Bohlbro AS**, et al. (2021) Active case-finding of tuberculosis in general populations and at-risk groups: A systematic review and meta-analysis. *European Respiratory Journal* **58**, 2100090.
[28] **Loredo C**, et al. (2014) Yield of close contact tracing using two different programmatic approaches from tuberculosis index cases: a retrospective quasi-experimental study. *BMC Pulmonary Medicine* **14**, 133.
[29] **Shah NS**, et al. (2014) Yield of contact investigations in households of patients with drug-resistant tuberculosis: systematic review and meta-analysis. *Clinical Infectious Diseases* **58**, 381–391.
[30] **Grandjean L**, et al. (2015) Transmission of multidrug-resistant and drug-susceptible tuberculosis within households: a prospective cohort study. *PLOS Medicine* **12**,e1001843.
[31] **Mhimbira FA**, et al. (2017) Interventions to increase tuberculosis case detection at primary healthcare or community-level services. *The Cochrane Database of Systematic Reviews* **11**, CD011432.
[32] **Deiss RG**, et al. (2009) Tuberculosis and illicit drug use: review and update. *Clinical Infectious Diseases* **48**, 72–82.
[33] **Mathema B**, et al. (2017) Drivers of tuberculosis transmission. *The Journal of Infectious Diseases* **216**, S644–S653.
[34] **Arriaga MB**, et al. (2021) The effect of diabetes and prediabetes on mycobacterium tuberculosis transmission to close contacts. *The Journal of Infectious Diseases* **224**, 2064–2072.
[35] **Reichler MR**, et al. (2020) Risk factors for tuberculosis and effect of preventive therapy among close contacts of persons with infectious tuberculosis. *Clinical Infectious Diseases* **70**, 1562–1572.
[36] **Rajan JV**, et al. (2017) Diabetes increases the risk of recent-transmission tuberculosis in household contacts in São Paulo, Brazil. *The International Journal of Tuberculosis and Lung Disease* **21**, 916–921.
[37] **Jia Z**, et al. (2014) Tuberculosis burden in China: a high prevalence of pulmonary tuberculosis in household contacts with and without symptoms. *BMC Infectious Diseases* **14**, 64.
[38] **Hamilton K**, et al. (2018) A systematic review of active case-finding strategies for tuberculosis in homeless populations. *The International Journal of Tuberculosis and Lung Disease* **22**, 1135–1144.
[39] **Liu Y**, et al. (2020) Tuberculosis among newly arrived immigrants and refugees in the United States. *Annals of the American Thoracic Society* **17**, 1401–1412.
[40] **Saunders MJ**, et al. (2014) Predictors of contact tracing completion and outcomes in tuberculosis: a 21-year retrospective cohort study. *The International Journal of Tuberculosis and Lung Disease* **18**, 640–646.

https://doi.org/10.1017/S0950268824001675 Published online by Cambridge University Press