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Effects of conditional cash transfers on tuberculosis incidence and mortality according to race, ethnicity and socioeconomic factors in the 100 Million Brazilian Cohort

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Conditional cash transfer (CCT) programs have been implemented globally to alleviate poverty. Although tuberculosis (TB) is closely linked to poverty, the effects of CCT on TB outcomes among populations facing social and economic vulnerabilities remain uncertain. Here we estimated the associations between participation in the world's largest CCT program, the Brazilian Bolsa Família Program (BFP), and the reduction of TB incidence, mortality and case-fatality rates using the nationwide 100 Million Brazilian Cohort between 2004 and 2015. We also evaluated these relationships according to race, ethnicity, wealth levels, sex and age. Exposure to the BFP was associated with a large reduction in TB incidence (adjusted rate ratio (aRR): 0.59; 95% confidence interval (CI): 0.58–0.60) and mortality (aRR: 0.69; 95% CI: 0.65–0.73). The strongest BFP association was observed in individuals of Indigenous ethnicity both for TB incidence (aRR: 0.37; 95% CI: 0.32–0.42) and mortality (aRR: 0.35; 95% CI: 0.20–0.62), and in individuals of Black and Pardo ethnicity (incidence—aRR: 0.58; 95% CI: 0.57–0.59; mortality—aRR: 0.69; 95% CI: 0.64–0.73). BFP associations were considerably stronger among individuals living in extreme poverty both for TB incidence (aRR: 0.49; 95% CI: 0.49–0.50) and mortality (aRR: 0.60; 95% CI: 0.55–0.65). CCT can strongly reduce TB incidence and mortality in individuals living in extreme poverty, and of Indigenous, Black and Pardo ethnicity, and could significantly contribute to achieving the End TB Strategy targets and TB-related Sustainable Development Goals.

Conditional cash transfers (CCTs) are the world's most widely implemented interventions for poverty alleviation[1]. Social protection, poverty alleviation and multisectoral actions on broad tuberculosis (TB) determinants are acknowledged as key pillars of the End TB Strategy by 2035, and they are essential to reduce the TB burden[2].

CCT programs have the potential to positively influence TB prevention, diagnosis and treatment[3,4]. CCTs improve living conditions and incentivize behavioral changes by providing financial support to individuals or households who adhere to specific health-related conditions, often associated with child and maternal health[5]. Previous studies in low- and middle-income countries showed that CCT programs were associated with improved TB outcomes, including increased treatment adherence and completion rates[6–8]. Furthermore, CCTs could effectively alleviate the economic burdens faced by TB-affected households[9]. These costs, which often result from medical expenses, loss of income and other related factors, can push affected households into poverty and hinder their access to proper TB care[10]. Thus, these transfers help mitigate the catastrophic costs associated

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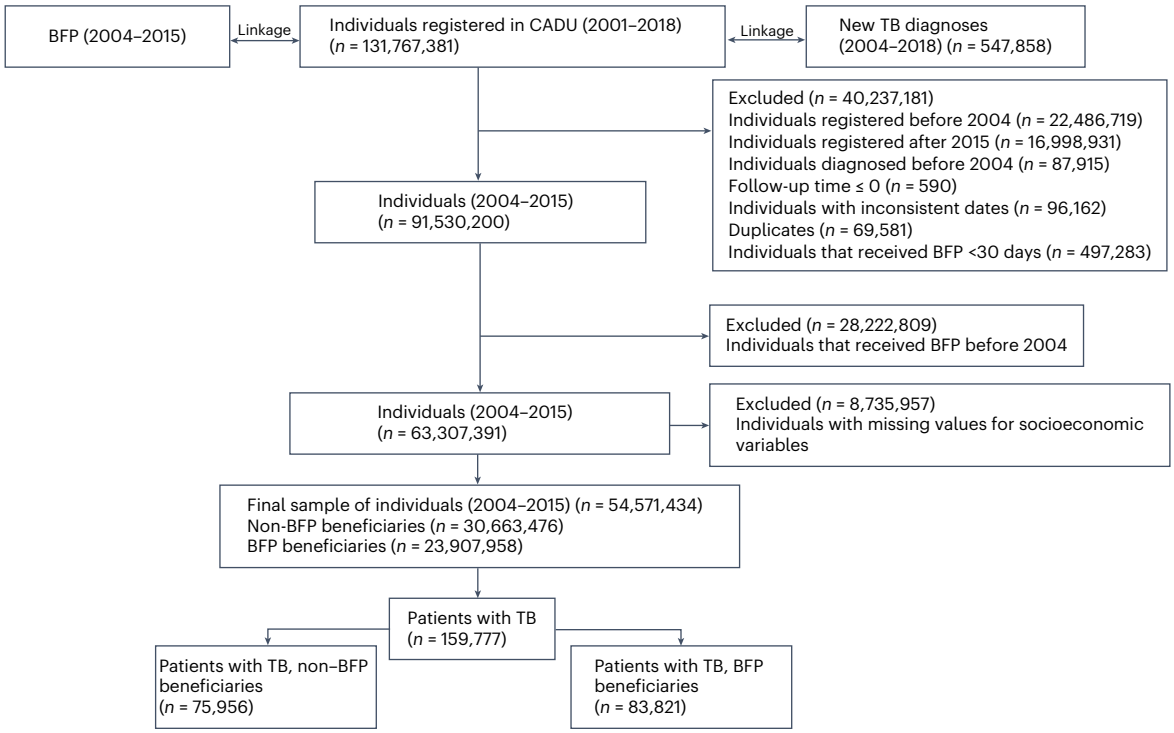

Fig. 1 | Flowchart of the selection of the study population from the 100 Million Brazilian Cohort, 2004–2015. Individuals from the 100 Million Brazilian Cohort were selected or excluded based on the study period (2004–2015) and availability of complete information of demographic and socioeconomic variables. A total of 54,571,434 individuals were selected: BFP beneficiaries (43.8%, *n* = 23,907,958) and non-BPF beneficiaries (56.2%, *n* = 30,663,476). The selected population included 159,777 new TB diagnoses.

with TB, ensuring better access to treatment and reducing economic hardships for affected families.

Since 2004, Brazil has implemented one of the world's largest CCT programs, the Bolsa Família Program (BFP)[11,12]. The governmental program provides direct cash transfers to households living in poverty with income below the poverty line defined by the Brazilian government as US$43.6 per person per month (at an exchange rate of 5 Brazilian Reais to US$1). The monthly cash benefits are at least US$120; children in the family aged between 0 and 6 years old receive an additional US$50, and pregnant women, children and adolescents up to 18 years old receive an additional of US$10 (values corrected in 2023). To continue receiving the benefits, BFP beneficiaries have to fulfill specific conditionalities related to healthcare for pregnant women (carrying out prenatal care) and children (compliance with the national vaccination schedule, monitoring nutritional status) and education (school attendance) for children and adolescents[13]. The BFP has been able to improve the well-being of families in poverty, and to reduce social and income inequalities in society, improving access to education, food and health services[11]. Several studies have shown the positive effects of the BFP on health outcomes such as child mortality[12], cardiovascular diseases[14], suicide[15], leprosy[16] and some aspects of the TB burden[3,17], among others.

In addition to the income disparity, Brazil has a profound ethnic and racial inequality. Individuals with self-declaration of Black, Pardo and Indigenous ethnicity in Brazil face more barriers to accessing better job opportunities, salaries, decent housing, a balanced diet, and quality health and education services[18]. As a consequence, these populations are more subject to violence and worse health indicators[18], including higher incidence of and mortality rates from TB[19].

We are not aware of previous studies that have systematically evaluated the effects of CCT programs in large cohorts of vulnerable individuals at high risk for TB and with limited access to health services, such as groups in situations of social marginalization and individuals living in extreme poverty, analyzing their effects according to subpopulation characteristics and evaluating the association between the participation in CCT and TB burden indicators. This study aimed to evaluate the comprehensive association between receipt of the BFP and the reduction of TB incidence, mortality and case-fatality rates using a nationwide cohort of 54.5 million low-income Brazilians over 12 years, estimating its heterogeneous effectiveness across the spectrum of ethnoracial factors and socioeconomic conditions.

Results

Study design and population

This study has a cohort study design, obtained after selecting individuals from the 100 Million Brazilian Cohort[20], a consolidated cohort created through the validated linkage[21] between the Federal Government Unified Registry for Social Programs (Cadastro Único)—which gathers data from the poorest half of the Brazilian population—and health-related datasets from the Brazilian Ministry of Health. As described in the flowchart of the study population selection (Fig. 1), after individuals who were outside the study period 2004–2015 and who had missing information on demographic or socioeconomic variables were excluded, 54,571,434 individuals were selected, of which 23,907,958 were BFP beneficiaries (43.8%) and 30,663,476 were non-BFP beneficiaries (56.2%), with a total of 159,777 new TB diagnoses and 7,993 TB deaths.

TB incidence was lower among BFP beneficiaries than among non-beneficiaries (49.44/100,000 person-years at risk (pyr) (95% confidence interval (CI): 47.84–48.50) versus 81.37/100,00 pyr (95% CI: 80.97–82.13)), and the same was the case with TB mortality rate (2.08/100,000 pyr (95% CI: 2.01–2.15) versus 4.68/100,000 pyr (95% CI: 4.54–4.81)) and TB case-fatality rate (0.68/100 pyr (95% CI: 0.64–0.73) versus 1.37/100 pyr (95% CI: 1.25–1.49)) (Table 1). BFP beneficiaries and non-beneficiaries showed similar demographic and socioeconomic

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Table 1 | Descriptive analyses of BFP beneficiaries and non-beneficiaries (*n*=54,571,434), Brazil, 2004–2015

	N-BF (*n*=30,663,476)		BF (*n*=23,907,958)			
	Rates (95% CI)	Number (%)	Rates (95% CI)	Number (%)	Total	
Incidence rate	81.37 (80.97–82.13)	75,956 (47.5)	49.44 (47.84–48.50)	83,821 (52.5)	159,777	
Mortality rate	4.68 (4.54–4.81)	4,359 (54.5)	2.08 (2.01–2.15)	3,634 (45.5)	7,993	
Case-fatality rate	1.37 (1.25–1.49)	495 (39.7)	0.68 (0.64–0.73)	751 (60.3)	1,246	
Social and demographic variables	**Number or mean**	**% or s.d.**	**Number or mean**	**% or s.d.**	***P* value[a]**	**SMD**
Sex					<0.001	0.0442
Male	14,595,815	47.6	10,854,212	45.4		
Female	16,067,661	52.4	13,053,746	54.6		
Age	25.32	2.14	24.17	1.60	<0.001	0.3829
Race or ethnicity					<0.001	0.1655
White	11,376,150	37.1	7,244,111	30.3		
Black or Pardo[b]	19,195,336	62.6	16,424,767	68.7		
Indigenous	91,990	0.3	239,080	1.0		
Education					<0.001	0.1986
Illiterate, never attended school	9,965,630	32.5	8,869,852	37.1		
Elementary school	9,536,341	31.1	7,459,283	31.2		
High school	6,040,705	19.7	5,140,211	21.5		
More than high school	5,120,800	16.7	2,438,612	10.2		
House construction materials					<0.001	0.0854
Bricks or cement	24,438,790	79.7	18,217,864	76.2		
Wood and other vegetal materials	6,224,686	20.3	5,690,094	23.8		
Number of people in the family					<0.001	0.3215
≤2	10,425,582	34.0	5,044,579	21.1		
3 or 4	14,810,459	48.3	12,432,138	52.0		
≥5	5,427,435	17.7	6,431,241	26.9		
Per salary expenses—% MW[c]					<0.001	0.2856
Below median	13,461,266	43.9	13,866,616	58.0		
Above median	17,202,210	56.1	10,041,342	42.0		
Lighting					<0.001	0.2021
Electricity	27,321,157	89.1	19,604,526	82.0		
Non-electric[d]	3,342,319	10.9	4,303,432	18.0		
Adequate sanitation[e]					<0.001	0.0795
Yes	19,961,923	65.1	14,655,578	61.3		
No	10,701,553	34.9	9,252,380	38.7		
Garbage disposal[f]					<0.001	0.1044
Garbage collection	24,745,425	80.7	18,265,680	76.4		
Burned or buried	5,918,051	19.3	5,642,2788	23.6		
Water supply					<0.001	0.1255
Public network	23,334,905	76.1	16,879,018	70.6		
Other[g]	7,328,571	23.9	7,028,940	29.4		
Incidence cohort	123.2	90.4	146.0	103.3	<0.001	−0.2361
AIDS					0.060	0.0183
Yes	1,355	8.8	3,009	9.3		
No	14,080	91.2	29,331	90.7		
Diabetes					<0.001	0.1085
Yes	1,236	8.0	1,716	5.3		
No	14,199	92.0	30,624	94.7		

Table 1 (continued) | Descriptive analyses of BFP beneficiaries and non-beneficiaries (*n*=54,571,434), Brazil, 2004–2015

	N-BF (*n*=30,663,476)		BF (*n*=23,907,958)			
	Rates (95% CI)	Number (%)	Rates (95% CI)	Number (%)	Total	
DOT					<0.001	0.0601
Yes	8,445	54.7	16,724	51.7		
No	6,990	45.3	15,616	48.3		
Pulmonary TB					<0.001	0.3733
Yes	13,373	86.6	28,422	87.9		
No	2,062	13.4	3,918	12.1		
PHC[h]	69.6	28.1	65.2	29.0	<0.001	0.1486
Specialized clinics per 1,000 inhabitants	0.12	0.14	0.10	0.12	<0.001	0.1535
Doctors per 1,000 inhabitants	1.17	1.01	1,21	0.99	<0.001	−0.0311
Nurses per 1,000 inhabitants	0.58	0.38	0.54	0.35	<0.001	0.3551
Unemployment rate (%)	7.3	5.0	8.98	5.2	<0.001	−0.3674
Gini index	52.3	7.1	54.2	6.9	<0.001	−0.2793
Year of entry into the cohort					<0.001	−0.5093
2004	2,177,107	7.1	2,438,612	10.2		
2005	1,318,529	4.3	1,936,545	8.1		
2006	5,396,772	17.6	6,072,621	25.4		
2007	3,403.646	11.1	2,103,900	8.8		
2008	2,269,097	7.4	1,267,122	5.3		
2009	1,379,856	4.5	2,175,624	9.1		
2010	1,993,126	6.5	1,864,821	7.8		
2011	1,655,828	5.4	1,673,557	7.0		
2012	3,526,300	11.5	1,601,833	6.7		
2013	2,054,453	6.7	1,147,582	4.8		
2014	3,035,684	9.9	884,594	3.7		
2015	2,422,415	7.9	741,147	3.1		
Obs	30,663,476		23,907,958			

BF beneficiaries; N-BF, non-beneficiaries; Obs, observations; SMD, standardized mean difference. [a]The following were used for a comparison between the groups: (1) two-tailed *t*-test for continuous variables and (2) Pearson's chi-squared test (χ^2) for categorical variables. [b]Race or ethnicity: Black or Pardo, self-declared. [c]Proportional to the baseline minimum wage (MW). [d]Lighting: non-electric—no meter, lamps, candles and others. [e]Percentage of the municipal population with inadequate baseline sanitation. [f]Percentage of the municipal population with baseline garbage collection. [g]Water supply: other—well, spring and others. [h]Primary healthcare (PHC) percentage coverage.

characteristics. Compared with non-beneficiaries, BFP beneficiaries are younger (mean age 25.3 versus 24.2 years) and had a slightly higher percentage of people self-identified as Black or Pardo race or ethnicity (62.6% versus 68.7%), people with no education (32.5% versus 37.1%), households with 3 or more individuals (66.0% versus 78.9%), people with lesser wealth (43.9% versus 58.0%), people without adequate sanitation (34.9% versus 38.7%) and people without a public network for water supply (23.9% versus 29.4%).

Main analyses

For the main statistical analysis, we used stabilized, truncated, inverse probability of treatment weighting (IPTW) multivariable Poisson regression models (see Methods for details). As shown in Table 2, the exposure to the BFP was associated with a significant reduction in TB incidence (adjusted rate ratio (aRR): 0.59; 95% CI: 0.58–0.60), decreased TB mortality (aRR: 0.69; 95% CI: 0.65–0.73) and lower TB case-fatality rate (aRR: 0.90; 95% CI 0.76–1.05), although not statistically significant.

Stratified analyses

In the stratified analyses according to wealth terciles (Table 3), the association between the BFP and the reduction of TB incidence showed a marked gradient and was considerably stronger among the individuals living in extreme poverty (aRR: 0.49; 95% CI: 0.49–0.50), gradually decreasing until having only a small association on the wealthiest individuals (aRR: 0.95; 95% CI: 0.93–0.98). Also, for TB mortality, the BFP association was considerably stronger among the individuals living in extreme poverty (aRR: 0.60; 95% CI: 0.55–0.65) and showed a gradient demonstrating the lack of association of the BFP in those people with higher wealth (aRR: 1.00; 95% CI: 0.85–1.17) (Table 3).

In the stratified analyses according to race and ethnicity, another gradient was evident among individuals of Indigenous, Black or Pardo, and White ethnicity, both for TB incidence (aRR: 0.37 (95% CI: 0.32–0.42) for Indigenous, aRR: 0.58 (95% CI: 0.57–0.59) for Black or Pardo, aRR: 0.67 (95% CI: 0.66–0.69) for White) and TB mortality (aRR: 0.35 (95% CI: 0.20–0.62) for Indigenous, aRR: 0.69 (95% CI: 0.64–0.73) for Black or Pardo, and aRR: 0.83 (95% CI: 0.73–0.94) for White), while the estimates for TB case-fatality rate was not statistically significant (Table 3). In terms of education, the association between the BFP and reductions in TB incidence was greater in people with less education (aRR: 0.58 (95% CI: 0.57–0.59) versus aRR: 0.80 (95% CI: 0.77–0.83) for people with higher education) (Table 3). The BFP was also associated with a higher reduction in TB mortality rates in females than in males

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Table 2 | Estimates of the association between the BFP and tuberculosis incidence, mortality and the case-fatality rate in the Brazil adjusted Poisson model (with robust standard errors), 2004–2015

Adjusted model	Outcomes, aRR (95% CI)		
	Incidence	Mortality	Case-fatality rate
BFP	0.59 (0.58–0.60)	0.69 (0.65–0.73)	0.90 (0.76–1.05)
Sex			
Male	1 (base)	1 (base)	1 (base)
Female	0.58 (0.57–0.59)	0.40 (0.38–0.42)	0.69 (0.59–0.79)
Age[a]	1.19 (1.19–1.20)	1.63 (1.61–1.65)	1.44 (1.38–1.50)
Race or ethnicity			
White	1 (base)	1 (base)	1 (base)
Black or Pardo[b]	1.42 (1.40–1.44)	1.70 (1.60–1.81)	1.02 (0.86–1.21)
Indigenous	3.63 (3.43–3.84)	4.50 (3.59–5.65)	1.58 (0.92–2.70)
Education			
Illiterate, never attended school	1 (base)	1 (base)	1 (base)
Elementary school	1.83 (1.80–1.86)	1.05 (0.99–1.11)	0.94 (0.79–1.12)
High school	2.21 (2.17–2.25)	0.99 (1.93–1.06)	0.77 (0.62–0.94)
More than high school	1.74 (1.70–1.77)	0.60 (0.54–0.67)	0.52 (0.37–0.73)
House construction materials			
Bricks and cement	1 (base)	1 (base)	1 (base)
Wood and other vegetal materials	1.22 (1.20–1.24)	1.21 (1.14–1.29)	1.15 (0.98–1.37)
Number of people in the family			
≤2	1 (base)	1 (base)	1 (base)
3 to 4	0.97 (0.96–0.99)	0.83 (0.78–0.88)	0.89 (0.89–1.28)
≥5	1.20 (1.18–1.21)	0.99 (0.92–1.06)	1.07 (0.76–1.05)
Per-salary expenses—% MW[c]			
Below the median	1 (base)	1 (base)	1 (base)
Above the median	0.77 (0.78–0.79)	0.71 (0.66–0.75)	0.89 (0.75–1.05)
Lighting			
Electricity	1 (base)	1 (base)	1 (base)
Non-electric[d]	1.34 (1.32–1.36)	1.54 (1.45–1.65)	1.09 (0.91–1.31)
Inadequate sanitation[e]	1.00 (0.99–1.02)	1.08 (1.02–1.15)	0.96 (0.81–1.14)
Garbage disposal[f]	0.78 (0.77–0.80)	0.77 (0.71–0.83)	1.03 (0.82–1.30)
Water supply			
Public network	1 (base)	1 (base)	1 (base)
Other[g]	0.95 (0.93–0.96)	0.99 (0.92–1.06)	0.95 (0.79–1.15)
TB incidence cohort	1.00 (1.00–1.00)	1.00 (1.00–1.00)	0.99 (0.99–1.00)
AIDS	–	–	1.93 (1.39–2.68)
Diabetes	–	–	0.87 (0.68–1.10)
DOT	–	–	1.54 (1.34–1.77)
Pulmonary TB	–	–	0.54 (0.42–0.69)
PHC[h]			
Coverage	1 (base)	1 (base)	1 (base)
No coverage	0.99 (0.99–1.00)	1.00 (0.99–1.00)	1.00 (0.99–1.00)
Specialized clinics per 1,000 inhabitants	0.63 (0.59–0.67)	0.54 (0.39–0.73)	1.15 (0.54–2.42)
Doctors per 1,000 inhabitants	1.11 (1.10–1.12)	1.19 (1.00–1.10)	1.08 (0.94–1.25)
Nurses per 1,000 inhabitants	0.95 (0.92–0.98)	0.80 (0.70–0.91)	1.11 (0.75–1.66)
Unemployment rate (%)	1.01 (1.01–1.02)	1.03 (1.02–1.04)	1.00 (0.98–1.02)
Gini index	0.99 (0.99–1.00)	1.00 (0.99–1.00)	0.98 (0.97–1.00)
Year of entry into the cohort	Yes	Yes	Yes
Obs	54,565,735	54,571,434	46,344

[a]Age categorized every 10 years. [b]Race or ethnicity: Black or Pardo, self-declared. [c]Proportional to the baseline MW. [d]Lighting: non-electric—no meter, lamps, candles and others. [e]Percentage of the municipal population with inadequate baseline sanitation. [f]Percentage of the municipal population with baseline garbage collection. [g]Water supply: other—well, spring and others. [h]Percentage of coverage.

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Table 3 | Estimates of the association between the BFP and TB incidence, mortality and case-fatality rate in Brazil in adjusted Poisson models (with robust standard errors), 2004–2015

Adjusted models	Incidence		Mortality		Case-fatality rate	
	aRR	95% CI	aRR	95% CI	aRR	95% CI
Wealth[a]						
Lower wealth	0.49	(0.49–0.50)	0.60	(0.55–0.65)	0.80	(0.64–1.01)
Obs	18,476,834		18,479,518		20,752	
Medium wealth	0.55	(0.54–0.57)	0.69	(0.63–0.77)	1.08	(0.82–1.43)
Obs	17,714,018		17,715,984		16,74	
Higher wealth	0.95	(0.93–0.98)	1.00	(0.85–1.17)	0.92	(0.60–1.42)
Obs	18,596,773		18,597,844		8,979	
Race or ethnicity						
White	0.67	(0.66–0.69)	0.83	(0.73–0.94)	1.26	(0.93–1.71)
Obs	18,612,330		18,613,587		12,288	
Black or Pardo[b]	0.58	(0.57–0.59)	0.69	(0.64–0.73)	0.84	(0.69–1.00)
Obs	35,641,321		35,645,701		33,328	
Indigenous	0.37	(0.32–0.42)	0.35	(0.20–0.62)	0.16	(0.007–3.33)
Obs	312,084		312,146		717	
Education						
Illiterate, never attended school	0.58	(0.57–0.59)	0.72	(0.68–0.78)	0.90	(0.66–1.23)
Obs	35,830,269		35,833,532		7,741	
Elementary school	0.58	(0.57–0.60)	0.63	(0.56–0.71)	0.93	(0.71–1.21)
Obs	11,160,783		11,162,535		17,185	
High school and university education	0.80	(0.77–0.83)	0.90	(0.71–1.14)	1.06	(0.84–1.35)
Obs	7,577,703		7,578,387		25,267	
Sex						
Male	0.60	0.59–0.61	0.78	0.72–0.84	0.94	0.78–1.13
Obs	25,432,661		25,435,955		25,681	
Female	0.61	0.59–0.62	0.63	0.57–0.69	0.90	0.66–1.23
Obs	29,142,346		29,144,751		20,663	
Prisons in the municipality						
Yes	0.62	0.61–0.64	0.74	0.68–0.80	0.92	0.75–1.15
Obs	26,078,654		26,081,968		26,777	
No	0.55	0.54–0.56	0.64	0.59–0.70	0.89	0.71–1.25
Obs	28,487,075		28,489,460		19,567	
Brazilian region						
North	0.48	0.47–0.50	0.47	0.39–0.56	0.97	0.55–1.71
Obs	6,224,529		6,225,218		5,859	
Northeast	0.51	0.49–0.52	0.57	0.52–0.63	0.81	0.63–1.06
Obs	18,246,282		18,248,820		14,703	
Southeast	0.67	0.66–0.68	0.88	0.80–0.97	1.09	0.82–1.44
Obs	19,438,441		19,439,952		17,926	
South	0.66	0.64–0.69	0.68	0.56–0.82	0.62	0.44–0.87
Obs	6,306,963		6,307,614		5,775	
Middle-West	0.58	0.54–0.62	0.68	0.50–0.92	1.37	0.56–3.36
Obs	4,349,514		4,349,824		2,081	

All models were adjusted for the same demographic and socioeconomic variables described in Table 2. [a]Measured by per capita expenses proportional to the baseline MW in terciles 1, 2 and 3, 33,33% each one; lower wealth: tercile 1, medium wealth: tercile 2 and higher wealth: tercile 3. [b]Race or ethnicity: Black or Pardo, self-declared.

(aRR: 0.63 (95% CI: 0.57–0.69) versus aRR: 0.78 (95% CI: 0.72–0.84), respectively). According to analyses by Brazilian regions, the strongest associations between the BFP and both TB incidence and mortality reductions were observed in the poorest areas, specifically the north and northeast regions. When carrying out a stratified analysis according to the existence or not of prisons in the municipality, we observed

a greater association between the BFP and reductions in TB incidence (aRR 0.55 (95% CI: 0.54–0.56) versus aRR 0.62 (95% CI: 0.61–0.64)) and mortality (aRR 0.64 (95% CI: 0.59–0.70) versus aRR 0.74 (95% CI: 0.68–0.80)) in municipalities without prisons.

Sensitivity and triangulation analyses

We developed a wide range of several sensitivity analyses (for details, see Methods and Supplementary Tables 1–7), fitting models with different specifications and adjusting variables. We also performed two different triangulation analyses[22]: Cox multivariate regression and propensity score matching (PSM) (Extended Data Table 4). All sensitivity tests confirmed the association estimates, and the triangulation analyses showed a high degree of confidence in the causal inference.

Discussion

In this study, we systematically analyzed the BFP effect among individuals living in situations of social marginalization, evaluating the associations between participation in a CCT and the burden of TB according to their ethnoracial and socioeconomic conditions. We observed strong effects of the BFP in decreasing both TB incidence and mortality rates. Notably, the effectiveness of the BFP showed a marked gradient based on race, ethnicity and socioeconomic conditions, revealing significantly stronger effects among individuals with Indigenous or Black or Pardo ethnicity and individuals living in extreme poverty.

Our findings reveal a gradient of BFP effectiveness based on the baseline wealth level of its beneficiaries: the BFP shows a significant effect on TB incidence and mortality in individuals living in extreme poverty, while demonstrating a lower effect on TB incidence in the less poor, with no discernible effects on TB mortality. The strongest effect of the BFP in the individuals living in extreme poverty can be explained by two factors. First, extreme poverty has consistently been shown to be a significant risk factor for TB, with TB risk levels correlating directly with poverty levels[4]. Therefore, lifting someone out of extreme poverty can be associated with a substantial reduction in their TB risk and burden. In addition, BFP benefits increase with poverty levels, providing a more significant improvement in socioeconomic position for individuals living in extreme poverty compared with those living in poverty, resulting in a more pronounced reduction in TB risk and burden for the former group.

Regarding the mechanisms by which CCT can affect TB, it has to be considered that the BFP, through the direct transfer of money to the families living in extreme poverty and in situations of social marginalization in Brazil, promotes greater access to food, both in quantity and quality, reducing food insecurity and malnutrition, an important TB risk factor, besides improving immune host defenses[11]. Moreover, housing conditions could improve, reducing crowding and poor ventilation, which are also recognized risk factors for TB[23]. Households could also transition from cooking with burning fuels such as wood, charcoal, coal and kerosene to cleaner fuels. This change can help reduce indoor air pollution, which has been recognized as a factor contributing to increased TB incidence. Smoking habits and alcoholism, which are strongly associated with poverty, could also decrease among BFP beneficiaries, thereby reducing the risk of contracting TB. The prevalence of diabetes, HIV and AIDS, which is higher in the individuals living in social vulnerability, could also be reduced by poverty-reduction interventions[24–26]. Consequently, this reduction can be associated with a decrease in the incidence and mortality from TB. Moreover, individuals affected by TB who are living in extreme poverty are more likely to avoid seeking diagnosis at health centers or to interrupt their treatment owing to direct costs, such as transportation expenses, and opportunity costs, such as the difficulty of missing a day of work due to their precarious employment and subsistence conditions. These costs could represent a barrier even if prevention, diagnosis and treatment are available free in the Unified Health System (Sistema Único de Saúde)[27]. In addition to providing monetary transfers, the conditions that qualify for the BFP could also contribute to reducing TB. These conditions are linked to requirements such as school attendance, education and access to health services for pregnant women and children under 5 years old, which could facilitate the recognition and early diagnosis of TB[13]. In summary, the BFP promotes a greater access to income, food and healthcare. This can be associated with a reduction on TB incidence, facilitate TB early diagnosis and treatment adherence, increase the TB cure rate[3,28,29] and reduce complications and death from the disease[30].

Moreover, we found that the BFP has a strong reduction effect on TB incidence and mortality in Indigenous populations in Brazil, who have a significantly higher risk of TB infection and mortality[31]. While this could be explained by the same mechanisms listed above, particularly in the context of Indigenous populations, the receipt of the BFP could alleviate extreme poverty and socioeconomic vulnerability. This could reduce food insecurity and malnutrition, which are particularly high among Indigenous populations, and lessen the significant geographic barriers that hinder access to even basic healthcare services[32].

It is worth elucidating the greater effect of the BFP on TB incidence among people of Black and Pardo race and ethnicity as more than 60% of new diagnoses of pulmonary TB in Brazil occurred among people who self-identified as Black and Pardo[19]. This could potentially be explained by the identical mechanisms detailed earlier. Particularly among individuals of Black and Pardo ethnicity in Brazil, the BFP could act on historical and structural social inequities[18,33], increasing income and improving education through its conditionalities, providing access to health services and, in this way, reducing the TB burden. The mechanisms described above can also explain the greater effect of the BFP in the north and northeast regions, which are the poorest and less developed areas of the country, with the worst infrastructures and healthcare resources[34].

The BFP has also a stronger reduction effect on mortality from TB in women. This can be explained by the fact that a woman is often primarily responsible for the family in registering and receiving the BFP. Furthermore, pregnant and breastfeeding women follow the conditions for receiving the BFP (pre- and postnatal care, vaccination, and health and nutrition surveillance)[13]. In this way, women who benefit from the BFP have greater access to health services, which could be associated with a greater reduction in TB mortality in this group, when compared with men.

We also observed that the protective effects of the BFP and lower incidence and mortality are greater in municipalities that do not have prisons. Prisons usually act as 'institutional amplifiers' or 'reservoirs' of TB, affecting the TB incidence not only in prison but also in non-prison populations[35]. The lower effect of BFP in these municipalities could be attributed to the program not reaching these populations, or not affecting their infection dynamics, leading to a higher and more resilient level of TB incidence in the community despite the coverage of the BFP[36].

TB prevention and care for economically vulnerable populations became an even greater challenge during and after the COVID-19 (coronavirus disease) pandemic[37]. Each of these populations living in economic vulnerable conditions has specificities and complexities when it comes to implementing TB prevention, diagnosis and treatment interventions. Furthermore, inequalities linked to local contexts, health facilities, and social, behavioral and cultural factors can superimpose on the organization of health services, influencing the care provided to these populational groups[37]. In this sense, it becomes urgent to intensify the actions of prevention and comprehensive care aimed at people in situations of social vulnerability, as well as intersectoral articulations and the inclusion of TB in the agendas of Social Assistance and Human Rights, among others. For this purpose, an Inter-Ministerial Committee for the Elimination of Tuberculosis and Other Socially Determined Diseases was created in 2023 in Brazil[38].

Our study has certain limitations that should be acknowledged. The first limitation is that, despite our efforts to control for all relevant confounding variables and use propensity-score-based models with IPTW, these approaches may not fully account for unobservable confounding variables and for potential selection biases. To address this concern, we have developed a multifaceted approach. First, we used a wide range of adjusting variables related to demographic, socioeconomic, healthcare and environmental determinants at the individual, household and municipal level, in both the logistic regression, for the construction of the propensity score, and in the Poisson regression for the estimation of BFP effects. This approach has been successfully used in previous studies on the impact of BFP and other public interventions on several health outcomes[14–16,18,23,33]. Second, we incorporated as adjusting variable—in the logistic and Poisson models—the average municipal rate of the TB indicator over the study period for each outcome under study (incidence, mortality and case-fatality rate). These rates were estimated among individuals from the same municipalities in the cohort. This allowed us to adjust for baseline endemic levels of the specific TB outcome under study in the municipalities and, consequently, for potentially associated unobservable variables—controlling for selection biases correlating BFP implementation levels with endemic TB levels in the community. Third, extensive sensitivity analyses were conducted (Supplementary Tables 1–7 and Methods), showing that the inclusion of additional independent variables or the substitution of existing ones, besides many other changes in the models' specifications, did not significantly affect the BFP effect estimates. Fourth, to increase our confidence in the causal inference, and eliminate the possibility of significant selection biases, we performed two different triangulation analyses: survival analysis with Cox regressions and PSM (Extended Data Table 4), showing that even with different methodological approaches, BFP effect estimates were still strong and statistically significant.

Another limitation is related to the external validity of our study: the 100 Million Brazilian Cohort—and our derived study cohort—consist of individuals obtained from the linkage between the Unified Registry for Social Programs (Cadastro Único (CADU)) and health data. Individuals registered in the CADU represent the poorest half of the Brazilian population. As a consequence, our cohort includes only individuals with extremely low-income or low-income who need to be registered in the CADU to access governmental assistance programs. This limitation affects the external validity of the cohort at the national level, as high-income individuals are not represented.

Moreover, although the Notifiable Diseases Information System (Sistema de Informação de Agravos de Notificação (SINAN)) has high sensitivity in Brazil, there may be underreporting of TB notifications[19]. However, our study design and analytic strategy limit the possibility that underreporting could bias our results. Additionally, results from municipalities selected for the high quality of vital information and low under-notifications confirm our findings (Supplementary Table 6).

A third limitation is that individuals with missing information in any of the adjusting variables were excluded. Although this exclusion may enhance the internal validity of the study, as records with missing values are often considered of lower quality, it also partially limits the generalizability of the results. However, analyses that included individuals with missing values yielded similar BFP effect estimates (Supplementary Table 7).

In this study, it was not possible to perform a cost-effectiveness analysis owing to its additional complexity and to the need for data not available in our datasets.

Our study presents strengths that contribute to its overall value. Firstly, we leveraged a large longitudinal dataset, which, when combined with effect evaluation methods, allowed us to assess the effects of interventions on an unprecedented scale. This unique approach enabled us to include a significant number of individuals and subpopulations that are often overlooked or underrepresented in traditional epidemiological studies and randomized controlled trials. This comprehensive inclusion is crucial for policy evaluations, as it highlights the potential differential impacts of public interventions based on the characteristics and baseline conditions of the BFP beneficiaries. In addition, our study's strength lies in the extensive range of sensitivity analyses conducted. These analyses provided further validation and reinforcement of the study's findings, ensuring their robustness and reliability. Furthermore, using various triangulation analyses instilled a high level of confidence in the causal inference, further bolstering the credibility of our findings.

We conclude that CCT programs can greatly reduce the incidence of and mortality from tuberculosis, particularly among individuals living in extreme poverty and self-declared as Indigenous and Black or Pardo ethnicity, who are usually at higher risk for TB and its devastating impacts. Therefore, the expansion of CCT programs in low- and middle-income countries can significantly strengthen the global response to TB, reducing social inequalities in the TB burden and contributing to the achievement of the End TB Strategy and the TB-related Sustainable Development Goals.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41591-024-03381-0.

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Methods

Study design, population and ethics

This study has a cohort study design, based on the longitudinal information of 54.5 million individuals from 1 January 2004 to 31 December 2015 (the period for which tuberculosis data were available). First, we constructed a conceptual framework to explain the mechanisms of possible associations between CCT and TB outcomes and to drive the analysis (Extended Data Fig. 1). The study population was developed by selecting a subgroup of individuals of the 100 Million Brazilian Cohort[20], a consolidated cohort created through the validated linkage[21] between the Federal Government Unified Registry for Social Programs (CADU)—which gathers data from the Brazilian population living in poverty, identifying and characterizing low-income families for social program eligibility, and including information on exposure to the BFP—and health-related datasets from the Brazilian Ministry of Health. The selection criteria for the inclusion of the study population were individuals registered in the CADU, diagnosed or not with TB and who received or not the BFP for more than 30 days during the study period (from 2004 to 2015). And the exclusion criteria were (1) individuals with follow-up time of less than 1 day, duplicate individuals or individuals with inconsistent dates and (2) individuals with missing data for the demographic and socioeconomic adjusting variables. The selection process of the study cohort is detailed in the flowchart of Fig. 1.

The criteria for the development and consolidation of the 100 Million Brazilian Cohort, including handling of misclassification, underreporting and missing data, are described elsewhere[20].

Data sources, outcomes and intervention

Two individual-level health-related datasets were linked to CADU: the Notifiable Diseases Information System (SINAN) and the Mortality Information System (Sistema de Informação sobre Mortalidade (SIM)). SINAN contains records of notifiable diseases, including TB. SIM registers deaths by all causes, according to the International Classification of Diseases (ICD-10). The linkage codes and algorithms were built based on five identifiers: date of birth, municipality of residence, sex, name and mother's name of the individual in each database. The CADU and the health information datasets (SIM and SINAN) were individually matched in two steps, using The Centre for Data and Knowledge Integration for Health (Centro de Integração de Dados e Conhecimentos para a Saúde (CIDACS))—Record Linkage tool (version number 1). The quality of each link between CADU, SINAN and SIM has been extensively evaluated and validated[21]. An aggregate-level longitudinal dataset—containing a wide range of yearly municipal-level information on TB endemicity levels, municipal infrastructures and healthcare resources—was also linked to the cohort through the individuals' municipal code of residence.

Tuberculosis outcomes defined for the study were incidence, mortality and case-fatality rates. The beneficiary group was defined as eligible individuals who received BFP benefits for more than 30 days, and their exposure started with receipt of the benefit until the end of their follow-up. The non-beneficiary group was defined as individuals who had never benefited from the BFP throughout their follow-up period. In the case of non-receipt of the benefits, eligible individuals were classified in the non-beneficiary group.

Statistical analyses

First, in the descriptive analysis, we estimated the rates of the study outcomes as follows: (1) TB incidence: new TB diagnoses divided by person-years at risk and multiplied by 100,000; (2) TB mortality: TB deaths divided by person-years at risk and multiplied by 100,000; and (3) case-fatality rate: TB deaths among people affected by TB divided by person-years at risk and multiplied by 100. The follow-up time for each individual in the cohort, that is, person-years, started on the date of entry into the cohort until the date of TB diagnosis (for TB incidence), the date of death due to TB (for TB mortality rate), the date of death from other causes or the end date of the cohort (31 December 2015). For the TB case-fatality rate, the start date began with the date of diagnosis and ended with the TB-related death, the date of death from other causes or the final date of the cohort. Afterward, we performed a descriptive analysis of new people affected by TB and deaths according to each independent variable. At the individual level, the demographic and socioeconomic covariables were age, self-reported sex, self-identified race or ethnicity (White, Indigenous, Black and Pardo—these last categories were analyzed together), education, per capita expenditure (as a proxy for the per capita wealth and calculated as a percentage of the yearly minimum wage, categorized by above or below the median) and year of entry into the cohort. At the family level, the independent variables were related to household characteristics: number of people, water supply, household construction material, sanitation, garbage disposal and lighting. At the municipal level, the covariables were unemployment rate, Gini index and a set of variables related to health services: Family Health Strategy (Estratégia de Saúde da Família) coverage (the main model of primary healthcare in Brazil), the number of doctors, nurses and specialized clinics per 1,000 inhabitants. To control for any potential selection bias associating BFP implementation with endemic TB levels in the community, the mean TB incidence rate in the cohort during the study period was included as a covariate in the models. When the study outcome was the case-fatality rate, we also included clinical classification of TB, percentage of directly observed therapy (DOT), AIDS comorbidity and diabetes as independent variables. All the variables used in the study are described in the conceptual model (Extended Data Fig. 1).

To estimate the association between BFP exposure and TB incidence, mortality and case-fatality rates, we used multivariable Poisson regression models, adjusted for all the relevant demographic and socioeconomic confounding variables listed above, with follow-up time as an offset variable, robust standard errors and observations weighted through stabilized, truncated, IPTW[39,40]. Poisson regression models are common for cohort data analyses[41], and IPTW Poisson regression models have been used in cohort studies that investigate the impacts of public and social policies on health outcomes, including several evaluation studies that used the 100 Million Brazilian Cohort[14–16,25,42,43].

The process of IPTW consists of two primary stages. Initially, the likelihood, also known as the propensity, of encountering the risk factor or intervention under consideration is computed based on an individual's attributes (that is, propensity score). Subsequently, weights are calculated as the inverse of the propensity score. By applying these weights to the study's population, a simulated population is generated in which potential sources of bias are equally balanced between the exposed and unexposed groups[39,44].

We consider a scenario with two potential treatments: one involving exposure to the BFP (treatment) and the other being unexposed (control). Within the potential outcome's framework, each individual is associated with a pair of potential outcomes (TB outcomes): $Y_i(1)$ and $Y_i(0)$. These outcomes represent the results under the treatment and control conditions, respectively, when subjected to the same conditions. However, each individual is assigned either the treatment or control, but not both. We denote Z as an indicator variable for treatment (exposure to BFP) ($Z = 1$ for treatment and $Z = 0$ for control). Consequently, only a single outcome, Y_i, is observable for each individual: this is the outcome linked to the actual treatment they received. The observed outcome, denoted by $Y_i i$, is determined by $Y_i = Z_i Y_i(1) + (1 - Z_i) Y_i(0)$. Thus, Y_i is equivalent to $Y_i(0)$ if $Z_i(0)$, and is equivalent to $Y_i(1)$ if $Z_i(1)$. Let $\mathbf{X}$ represent a vector of observed baseline covariates. Initially, we used logistic regression to get the propensity score. The logistic regression equation models the probability of a binary outcome (usually 0 or 1) as a function of one or more predictor variables. The logistic function, also known as the sigmoid function,

is used to transform the linear combination of predictors into the probability of the event occurring.

$$P(Z=1 \mid \mathbf{X}) = \frac{1}{1+e^{-(\beta_0+\beta_1\mathbf{X}_1+\beta_2\mathbf{X}_2+\ldots+\beta_p\mathbf{X}_p)}}$$

where $P(Z=1|\mathbf{X})$ is the probability of the binary outcome being 1 given the predictor variables $\mathbf{X}$; e is the base of the natural logarithm; and $\beta_0, \beta_1, \beta_2, \ldots, \beta_p$ are the coefficients corresponding to the predictor variables $\mathbf{X}_1, \mathbf{X}_2, \ldots, \mathbf{X}_p$. We estimated the probability of each individual to receive the BFP (propensity score (PS)), in two ways. For the first equation, we calculated the marginal probability of treatment (PS_t) and then we estimated the multivariable PS (PS_{mul}), adjusted for all relevant covariates.

We used PS_t and PS_{mul} as weights to calculate the stabilized IPTW using the formulas:

$$w_{Z=1} = \frac{PS_t}{PS_{mul}} \quad w_{Z=0} = \frac{(1-PS_t)}{(1-PS_{mul})}$$

where $w_{Z=1}$ is the weight for the beneficiaries and $w_{Z=0}$ is the weight for the non-beneficiaries. To correct for possible extreme weights, we set thresholds, with weights exceeding the set value converted to that threshold value[45]. In this study, the weights were truncated based on the distribution of their values for the 1st and 99th percentiles, which represented these thresholds, as in previous similar studies[14–16,25,42,43]. IPTW uses the propensity score to balance baseline characteristics in the exposed and unexposed groups by weighting each individual by the inverse probability of receiving treatment[39,44].

The Poisson equation with IPTW is a framework used to analyze count data or event occurrences, while accounting for the potential bias introduced by non-random treatment assignment in observational studies. In this context, the Poisson equation models the relationship between the event outcomes and covariates while incorporating IPTW to adjust for treatment selection bias.

$$\log Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip} + \log \mathrm{IPTW}_i$$

where $\log Y_i$ is the natural logarithm of the rate for individual i; X_{i1}, X_{i2}, ..., X_{ip} are the covariates for individual i; β_0, β_1, β_2, ..., β_p are the coefficients associated with the covariates; and $\log \mathrm{IPTW}_i$ represents the logarithm of the inverse probability treatment weight for individual i. Finally, multivariable Poisson regressions, adjusted by stabilized, truncated IPTW, were estimated with the same socioeconomic and demographic variables adopted in the logistic model for all TB outcomes.

Moreover, to understand BFP association heterogeneity, we fitted these IPTW Poisson regression models stratified by age, sex, race and ethnicity, education, wealth terciles (per capita expenditure), existence of prisons in the municipality and Brazilian regions.

To confirm the robustness of the findings, we applied several sensitivity analyses: (1) we fitted the same regressions without and only with the TB endemicity level variable (Supplementary Tables 1 and 2); (2) we fitted models with only individual-level variables and tested the inclusion of different aggregate-level variables (Supplementary Table 3); (3) we estimated and compared all models without IPTW (Extended Data Table 5); (4) to evaluate the adoption of per capita expenses as a proxy for wealth, we carried out the same analyses with other proxies, such as per capita income (Supplementary Table 4); (5) we adjusted the same models with different specifications (including different sets of individual-level covariates, inclusion or exclusion of robust standard errors (Supplementary Table 5), only in municipalities with adequate vital information (Supplementary Table 6)); and (6) we redid the estimates including individuals with missing category (Supplementary Table 7). Finally, to have a greater degree of confidence in the causal inference of our impact evaluation, we performed two different triangulation analyses[22], verifying the existence of BFP associations also using alternative methods: survival analysis with Cox multivariate regression and PSM (Extended Data Table 4).

All statistical analyses were performed in Stata Version MP 15.1.

Inclusion and ethics statement

This project was designed through a longstanding partnership among the Institute of Collective Health (Instituto de Saúde Coletiva (ISC)) of the Federal University of Bahia (Universidade Federal da Bahia (UFBA)) and The Center for Data and Knowledge Integration for Health (CIDACS) of the Oswaldo Cruz Foundation (Fundação Oswaldo Cruz (FIOCRUZ)), both based in Salvador, Brazil. The 100 Million Brazilian Cohort was created by CIDACS in collaboration with ISC researchers, and the subset of data used for this study was selected and analyzed by a collaborating group of ISC and CIDACS researchers. All team members collaborated on data ownership, intellectual property and authorship of publications related to the work. Roles and responsibilities were agreed upon among collaborators ahead of the research. Previous work and articles from the analyses of these datasets, most of them developed by co-authors of this article, were used to guide the design of this study, as well as connect our findings to similar research, and have been considered in the citations for this paper.

Ethics approval

This study was approved by the Research Ethics Committee of the Institute of Collective Health of the Federal University of Bahia (ISC, UFBA), under number 41691315.0.0000.5030 (assessment number 3.783.920). In this study, participant consent was waived owing to the use of administrative data.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The data underlying this article will be shared on request to ISC of UFBA, and CIDACS of FIOCRUZ, and after ethical approval. All data supporting the findings presented were obtained from The Center for Data and Knowledge Integration for Health (CIDACS). Importantly, restrictions apply to access to the data, which contain sensitive information, were licensed for exclusive use in the current study and, due to privacy regulations from the Brazilian Ethics Committee, are not openly available. Upon request and with express permission from CIDACS (email: cidacs.curadoria@fiocruz.br) and approval from an ethical committee, controlled access to the data is possible. The dataset is registered under the following DOI handle: https://hdl.handle.net/20.500.12196/CIDACS/65, which provides metadata and a register of all versions of the database.

Code availability

The algorithms and code used in this Article will be shared on request to ISC of UFBA, and CIDACS of FIOCRUZ, and after ethical approval. Due to the confidentiality of the data and the presence of lines of code that deal with sensitive variables, their characteristics and their values, access to the codes will be granted upon request and with express permission from CIDACS (email: cidacs.curadoria@fiocruz.br) and approval from an ethical committee. If approved, the code will be available within 1 month from the initial application.

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Author contributions

G.S.J.: formal analysis—accessed and verified the data, investigation, methodology, and writing—original draft, review and editing. P.F.P.S.G.: formal analysis—accessed and verified the data, investigation, methodology, and writing—original draft, review and editing. D.M.C.: methodology, and writing—original draft, review and editing. A.F.S.: formal analysis—accessed and verified the data, investigation, methodology, and writing—original draft, review and editing. I.L.: formal analysis—accessed and verified the data, methodology, and writing—original draft, review and editing. M.Y.I.: data curation, funding acquisition, resources and writing—review and editing. M.L.B.: data curation, funding acquisition, resources, and writing—review and editing. M.N.S.: writing—original draft, review and editing. D.B.: writing—review and editing. D.R.: conceptualization, project administration, funding acquisition, investigation, methodology, supervision—accessed and verified the data, decision to submit the paper, and writing—review and editing.

Competing interests

The authors declare no competing interests.

Additional information

Extended data is available for this paper at https://doi.org/10.1038/s41591-024-03381-0.

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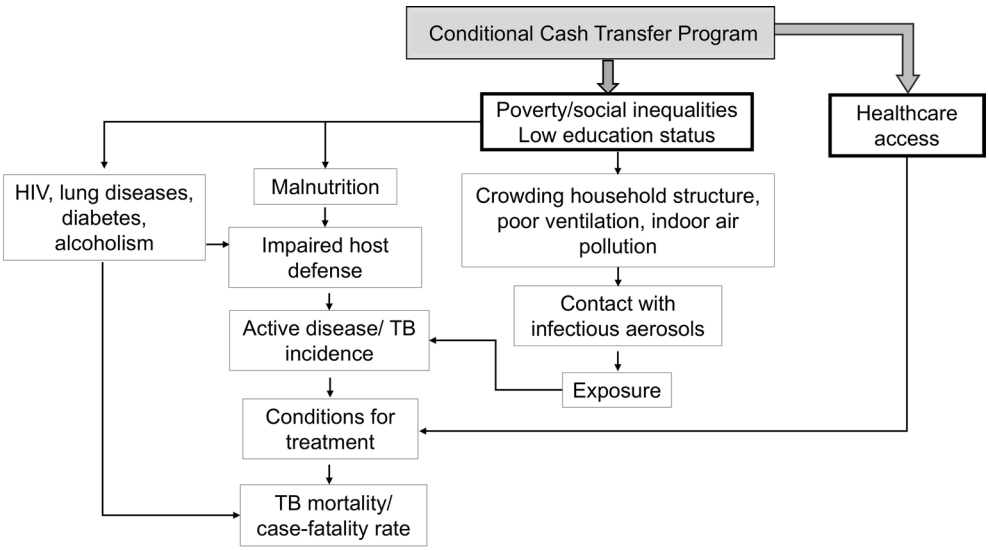

Extended Data Fig. 1 | Conceptual framework about determinants and possible effects of the conditional cash transfers (CCT) on tuberculosis (TB) outcomes. TB=Tuberculosis. Source: the authors.

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Extended Data Table 1 | Number of observations per Tuberculosis (TB) new case, death from TB and TB deaths among TB new cases by Bolsa Família Program (BFP) beneficiaries (BF) and non-beneficiaries (N-BF)

Variables	*Bolsa Família Program* (BFP[c])		
	N-BF	BF	Total
New TB cases[a]			
No	30,584,786	23,821,172	54,405,958
Yes	75,956	83,821	159,777
Total	30,660,742	23,904,993	54,565,735
TB deaths[b]			
No	30,659,117	23,904,324	54,563,441
Yes	4,359	3,634	7,993
Total	30,663,476	23,907,958	54,571,434
TB deaths/new TB cases[a,b]			
No	14,496	30,606	45,102
Yes	495	751	1,246
Total	14,991	31,357	46,348

Notes: a New Tuberculosis cases, defined with new cases, relapse cases of TB and re-entry by adapted by Brazilian Ministry of Health criteria; b Deaths from tuberculosis, considering as underlying cause the International Classification of Diseases (ICD-10) codes A15 to A19, J65, 0980 and P370. c *Bolsa Família* Program

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Extended Data Table 2 | Logistic regression prediction models for individuals benefiting or not from the Bolsa Família Program (BFP), for Tuberculosis (TB) incidence, mortality, and case-fatality rate, Brazil, 2004-2015. Estimates from the Propensity Score (PS)

	Outcomes (aRR[a] – CI[b] 95%)	
Adjusted Model	**Incidence and Mortality**	**Case-Fatality Rate**
Sex		
Male	1 (base)	1 (base)
Female	1.17 (1.17-1.18)	1.73 (1.65-1.81)
Age (years)	0.84 (0.84 - 0.85)	0.76 (0.75-0.77)
Race or ethnicity [c]		
White	1 base	1 (base)
Black and Pardo	1.15 (1.15-1.16)	1.25 (1.19-1.32)
Indigenous	3.09 (3.06-3.12)	3.50 (2.68-4.58)
Education		
Illiterate, never attended school	1 (base)	1 (base)
Elementary school	1.07 (1.07-1.08)	1.06 (0.99-1.14)
High school	1.08 (1.08-1.09)	0.93 (0.86-0.99)
More than high school	0.83 (0.83-0.84	0.65 (0.59-0.70)
Household construction material		
Bricks/cement	1 (base)	1 (base)
Wood, other vegetal materials [d]	0.94 (0.93-0.94)	0.91 (0.86-0.97)
Number of people in the family	1 (base)	1 (base)
2		
3 a 4	1.52(1.51-1.52)	2.03 (1.93-2.14)
> 5	2.03 (2.02-2.04)	3.56 (3.33-3.80)
Per salary expenses - % MW [e]		
Below median	1 (base)	1 (base)
Above median	0.88 (0.88-0.89)	0.51 (0.48-0.54)
Lighting		
Electricity	1 (base)	1 (base)
Non-electric [f]	1.22 (1.21-1.22)	1.53 (1.43-1.64)
Inadequate sanitation [g]	1.02 (1.02-1.03)	1.06 (1.00-1.12)
Garbage disposal	1.08 (1.08-1.09)	1.04 (0.96-1.12)
Water supply		
Public network	1 (base)	1 (base)
Other [h]	1.11 (1.11-1.12)	1.17 (1.10-1.25)
TB Incidence Cohort	1.00 (1.00- 1.00)	1.00 (1.00- 1.00)
AIDS	-	0.93 (0.86-1.01)
Diabetes	-	0.94 (0.86-1.03)
DOT	-	0.99 (0.94-1.04)
TB Classification	-	0.91 (0.85-0.97)
Primary Health Care		
Coverage	1 (base)	1 (base)
no coverage [i]	0.99 (0.99-0.99)	0.99 (0.99-0.99)
Specialized clinics per 1,000 inhabitants	0.27 (0.26-0.27)	0.27 (0.21-0.34)
Doctors per 1,000 inhabitants	1.14 (1.13-1.14)	1.17 (1.11-1.22)
Nurses per 1,000 inhabitants	0.99 (0.98-0.99)	0.84 (0.73-0.97)
Unemployment rate (%)	1.01 (1.01- 1.01)	1.01 (1.01- 1.02)
Gini index	1.01 (1.01- 1.01)	1.01 (1.01- 1.02)
Year of entry into the cohort	yes	yes
Obs.:	54,571,434	46,344

Abbreviations: a Adjusted Rate Risks. b Confidence interval. c Race or ethnicity: Black/Pardo self-declared. d Household construction Material: No – Coated clay, uncoated clay, wood, and others. e Proportional to the baseline minimum wage (MW) f Lighting: Non-electric – No meter, lamps, candles, and others. g % of the municipal population with inadequate baseline sanitation. h Water supply: Other – well, spring, and others. i Primary Health Care (PHC) percentage coverage.

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Extended Data Table 3 | Estimates by adjusted Poisson models of the association between the Bolsa Família Program (BFP) and Tuberculosis incidence, mortality and case-fatality rates stratified by wealth quartile, Brazil, 2004-2015)

Wealth[a]	Incidence[f]		Mortality[f]		Case-Fatality[f]	
	aRR[g]	95% CI[h]	aRR	95% CI	aRR	95% CI
			Wealth [c]			
Quartile 1[b]	0.49	(0.49-0.50)	0.60	(0.55-0.61)	0.80	(0.64-1.01)
Obs.	18,476,834		18,479,518		20,752	
Quartile 2[c]	0.48	(0.47-0.49)	0.56	(0.50-0.63)	0.86	(0.60-1.22)
Obs.	10,565,846		10,567,091		10,350	
Quartile 3[d]	0.71	(0.69-0.73)	0.86	(0.76-0.99)	1.20	(0.82-1.75)
Obs.	11,599,362		11,600,410		8,865	
Quartile 4[e]	0.99	(0.96-1.02)	1.01	(0.83-1.23)	0.86	(0.53-1.40)
Obs.	14,145,583		14,146,327		6,460	

Notes: a Measured by *per capita* expenses proportional to the baseline minimum wage (MW). b Quartile 1: 0% 0.1%. c Quartile 2: > 0.1% a 18.5%. d Quartile 3: >18.5% a 56.5%. e Quartile 4: > 56.5%. f Calculated by person-years at risk. g Adjusted rate risk h Confidence Interval

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Extended Data Table 4 | Estimates of the association between the Bolsa Família Program (BFP) and Tuberculosis (TB) incidence, mortality, and the case-fatality rate using Survival Analysis and Propensity Score Matching models, 2004-2015

Adjusted Model	Survival Analysis			Propensity Score Matching Analysis		
	Incidence	Mortality	Case-Fatality	Incidence	Mortality	Case-Fatality
	aHR[a] (CI[b] 95%)	aHR[a] (CI[b] 95%)	aHR[a] (CI[b] 95%)	aOR[c] (CI[b] 95%)	aOR[c] (CI[b] 95%)	aOR[c] (CI[b] 95%)
BFP[d]	0.54 (0.54-0.55)	0.65 (0.61-0.69)	1.04 (0.89-1.22)	0.43 (0.29-0.55)	0.32 (0.30-0.34)	0.53 (0.18-1.50)
Sex						
Male	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
Female	0.58 (0.58-0.59)	0.39 (0.37-0.41)	0.69 (0.60-0.79)	-0.16(-0.17:-0.16)	-0.16 (-0.17:-0.16)	0.69 (0.60-79)
Age[e]	1.18 (1.18-1.19)	1.62 (1.61-1.64)	1.47 (1.41-1.53)	0.16 (-0.17:-0.16)	0.16 (-0.17:-0.16)	1.47(1.41-1.53)
Race or ethnicity[f]						
White	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
Pardo/Black	1.42 (1.41-1.45)	1.70 (1.60-1.81)	1.03 (0.86-1.22)	0.14 (0.14-0.15)	0.14 (0.14-0.15)	1.03 (0.87-1.22)
Indigenous	3.70 (3.49-3.91)	4.56 (3.63-5.72)	1.38 (0.81-2.33)	1.13 (1.12-1.14)	1.13 (1.12-1.14)	1.38 (0.81-2.33)
Education						
Illiterate, never attended school	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
Elementary school	1.82 (1.79-1.85)	1.04 (0.98-1.10)	0.93(0.78-1.10)	0.07(0.71-0.74)	0.07(0.71-0.74)	0.93 (0.78-1.10)
High school	2.20(2.16-2.24)	0.98 (0.92-1.05)	0.78(0.63-0.95)	0.08 (0.08-0.08)	0.08 (0.08-0.08)	0.78 (0.63-0.95)
More than high school	1.72 (1.68-1.75)	0.60(0.53-0.67)	0.53(0.38-0.75)	-0.18 (-0.18:-0.17)	-0.18 (-0.18:-0.17)	0.53 (0.38-0.75)
Household construction material (brick)						
Yes	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
No[g]	1.22 (1.20-1.24)	1.21 (1.13-1.29)	1.14 (0.97-1.34)	-0.06 (-0.06:-0.05)	-0.06 (-0.06:-0.05)	1.14 (0.97-1.34)
Number of people in the family						
2	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
3 a 4	0.98 (0.97-0.99)	0.83(0.78-0.88)	0.91 (0.78-1.07)	0.41 (0.41-0.42)	0.41 (0.41-0.42)	0.91 (0.78-1.07)
> 5	1.21 (1.19-1.23)	1.00 (0.93-1.07)	1.05 (0.89-1.25)	0.70 (0.70-0.71)	0.70 (0.70-0.71)	1.05 (0.89-1.25)
Per salary expenses - % MW[h]						
below median	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
above median	0.77 (0.76-0.78)	0.70 (0.65-0.74)	0.89 (0.75-1.05)	-0.12 (-0.12:-0.12)	-0.12 (-0.12:-0.12)	0.89 (0.75-1.05)
Lighting						
Electricity	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
Non-electric[i]	1.35 (1.33-1.37)	1.55 (1.45-1.67)	1.19* (1.03-1.38)	0.19 (0.19-0.20)	0.22 (0.22-0.23)	1.10 (0.92-1.31)
Inadequate sanitation[j]	1.00 (0.99-1.02)	1.08 (1.02-1.14)	1.00 (0.99-1.01)	0.29 (0.27-0.30)	0.29 (0.27-0.30)	0.98 (0.83-1.15)
Garbage disposal	0.78 (0.77-0.80)	0.76(0.70-0.82)		0.08 (0.07-0.08)	0.08 (0.07-0.08)	1.00 (0.80-1.26)
Water supply						
Public network	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
Other[k]	0.95 (0.93-0.97)	0.99 (0.92-1.06)		0.11(0.11-0.11)	0.11(0.11-0.11)	0.98 (0.82-1.15)
Mun. average TB[l] incidence rate	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (0.99-1.00)	0.01 (0.01-0.01)	0.00 (0.00-0.00)	1.00 (0.99-1.00)
Primary Health Care[m]						
Coverage	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)	1 (base)
no coverage	1.00 (0.99-1.00)	0.99 (0.99-0.99)	1.00 (0.99-1.00)	-0.00 (-0.00:-0.00)	-0.00 (-0.00:-0.00)	1.00 (0.99-1.00)
Specialized clinics per 1,000 inhabitants	0.64 (0.60-0.68)	0.54 (0.39-0.73)	1.09 (0.52-2.26)	-1.30 (-1.31:-1.30)	-1.30 (-1.31:-1.30)	1.09 (0.52-2.26)
Doctors per 1,000 inhabitants	1.01 (1.01-1.13)	1.19 (1.14-1.25)	1.04 (0.91-1.20)	0.12 (0.12-0.13)	0.12(0.12-0.13)	1.04 (0.91-1.20)
Nurses per 1,000 inhabitants	0.93 (0.90-0.96)	0.78 (0.69-0.89)	1.12 (0.76-1.65)	-0.00 (-0.01:-0.00)	-0.00 (-0.01:-0.00)	1.12 (0.76-1.65)
Unemployment rate (%)	1.01 (1.01-1.02)	1.03(1.02-1.03)	1.01 (0.99-1.02)	0.01 (0.01-0.02)	0.01 (0.01-0.02)	1.01 (0.99-1.02)
Gini index	0.99 (0.99-1.00)	1.00 (0.99-1.00)	0.99 (0.98-1.00)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.99 (0.98-1.00)
Individual`s year of entry into the cohort	yes	yes	yes	yes	yes	yes
Obs.:	54,571,434	54,571,434	46,344	54,571,434	54,571,434	46,344

Notes: a Adjusted Hazard Ratio b Confidence interval. c Adjusted Odds Ratio d Bolsa Família Program e Age categorized every 10 years. f Race or ethnicity: self-declared. g Household construction material: No – Coated clay, uncoated clay, wood, and others. h Proportional to the baseline minimum wage (MW). i Lighting: Non-electric – No meter, lamps, candles, and others. j % of the municipal population with inadequate baseline sanitation. k Water supply: Other – well, spring, and others. l Tuberculosis m Primary Health Care (PHC) percentage coverage.

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Extended Data Table 5 | Estimates by adjusted Poisson models without inverse probability of treatment weighting (IPTW) of the association between the *Bolsa Família* Program (BFP) and Tuberculosis incidence, mortality, and the case-fatality rate, 2004-2015

	Outcomes (RR[a] – CI[b] 95%)		
Models	**Incidence**	**Mortality**	**Case-Fatality**
Adjusted	0.58 (0.57-0.58)	0.65 (0.62-0.69)	0.90 (0.77-1.03)
Unadjusted	0.59 (0.58-0.59)	0.44 (0.42-0.46)	0.49 (0.44-0.56)
Obs	54,565,735	54,571,434	46,344

Notes [a] Adjusted Rate Risk. [b] Confidence Interval

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Extended Data Table 6 | Estimates by adjusted Poisson models of the association between the Bolsa Família Program (BFP) and Tuberculosis incidence, mortality and case-fatality rate, Brazil, 2004-2015 - Modelling with interaction terms included in the logistic regression for the estimation of the Propensity Score

	Outcomes (aRR[a] – CI[b] 95%)		
Models	**Incidence**	**Mortality**	**Case-Fatality**
Adjusted	0.59 (0.58-0.60)	0.69 (0.65-0.73)	0.91 (0.78-1.06)
Obs	54,565,729	54,571,428	46,344

Notes: Interaction terms entered into logistic regression to estimate propensity score: sex *vs* race, sex *vs* wealth and race *vs* wealth. [a] Adjusted Rate Risk. [b] Confidence Interval.

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Extended Data Table 7 | Estimates by adjusted Poisson models of the association between the Bolsa Família Program (BFP) and Tuberculosis (TB) incidence, mortality and case-fatality rate, Brazil, 2004-2015 - includes time of exposure to BFP as cohort censoring

	Outcomes (aRR[a] – CI[b] 95%)	
	Incidence	**Mortality**
Adjusted Model	0.64 (0.63-0.65)	0.79 (0.75-0.84)
Obs	63,122,383	63,129,089

Notes: [a] Adjusted Rate Risk. [b] Confidence Interval.

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Extended Data Table 8 | Estimates by adjusted Poisson models of the association between the Bolsa Família Program (BFP) and Tuberculosis (TB) incidence, mortality and case-fatality rate in Brazil, 2004-2015 – includes as adjustment variable the existence of prisons per municipality

	Outcomes (aRR[a] – CI[b] 95%)		
	Incidence	**Mortality**	**Case-Fatality**
Adjusted Model	0.59 (0.58-0.60)	0.69 (0.65-0.73)	0.91 (0.78-1.06)
Obs	54,565,729	54,571,428	46,344

Notes: [a] Adjusted Rate Risk. [b] Confidence Interval.

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Extended Data Table 9 | Estimates by adjusted Poisson models (with robust standard errors) of the association between the Bolsa Família Program (BFP), and Tuberculosis (TB) incidence, mortality, and case-fatality rate in Brazil including the TB incidence in the municipality of residence and TB incidence standardized by age, 2004-2015

Model adjusted by	TB[a] incidence in the municipality of residence			TB[a] incidence standardized by age		
Outcomes	TB[a] incidence	TB[a] mortality	TB[a] case-fatality rate	TB[a] incidence	TB[a] mortality	TB[a] case-fatality rate
aRR[b] (CI[c]95%)	0.58 (0.57-0.59)	0.68 (0.64-0.72)	0.90 (0.77-1.05)	0.58 (0.57-0.59)	0.69 (0.65-0.73)	0.90 (0.77-1.05)

Notes: a Tuberculosis b Adjusted Rate Risk. c Confidence Interval.

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☐	☒ The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☐	☒ A description of all covariates tested
☐	☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☐	☒ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☐	☒ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☐	☒ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	The Centre for Data and Knowledge Integration for Health (Centro de Integração de Dados e Conhecimentos para a Saúde - CIDACS)-Record Linkage tool (verson number 1) was used to linkage. https://github.com/gcgbarbosa/cidacs-rl-v1
Data analysis	All statistical analyzes were performed in Stata Version MP 15.1

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

The data underlying this article will be shared on request to ISC/UFBA and CIDACS/Fiocruz and after ethical approval. All data supporting the findings presented were obtained from The Center for Data and Knowledge Integration for Health ((Centro de Integração de Dados e Conhecimentos para a Saúde - CIDACS). Importantly, restrictions apply to access to the data, which contains sensitive information, were licensed for exclusive use in the current study and, due to privacy

regulations from the Brazilian Ethics Committee are not openly available. Upon request and with express permission from CIDACS (mail to cidacs.curadoria@fiocruz.br) and approval from an ethical committee, controlled access to the data is possible. The dataset is registered under the following DOI handle: https://hdl.handle.net/20.500.12196/CIDACS/65, which provides metadata and a register of all versions of the database.

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	We only use the term sex, as in the following statements Data sources, outcomes, and intervention section: "The linkage codes and algorithms were built based on five identifiers: date of birth, municipality of residence, sex, name, and mother`s name of the individual in each database". Statistical Analyses section: "At the individual level, the demographic and socioeconomic covariables were age, sex, self-identified race/ethnicity (white, Indigenous, Black and pardo - these last categories were analysed together), education, per capita expenditure (as a proxy for the per capita wealth and calculated as a percentage of the yearly minimum wage, categorised by tertiles), and year of entry into the cohort" and "Moreover, in order to understand BFP effects heterogeneity, we fitted these IPTW Poisson regression models stratified by age, sex, race/ethnicity, education, and wealth- tertiles (per capita expenditure)."
Reporting on race, ethnicity, or other socially relevant groupings	We specify in the main text that the variables were obtained from The 100 Million Brazilians Cohort and that race/ethnicity is self-identified. Furthermore, we explain how we use the family wealth variable (per capita expenditures). Study design, population, and ethical issues: "The study population was achieved by selecting a subgroup of individuals of the 100 Million Brazilians Cohort, a consolidated cohort created through the validated linkage between the Federal Government Unified Registry for Social Programs (Cadastro Único) – that gathers data from the poorest half of the Brazilian population, identifying and characterising low-income families for social programs eligibility, and including information on exposure to the BFP - and health-related datasets from the Brazilian Ministry of Health's." Statistical Analyses section: "At the individual level, the demographic and socioeconomic covariables were age, sex, self-identified race/ethnicity (white, Indigenous, Black and pardo - these last categories were analysed together), education, per capita expenditure (as a proxy for the per capita wealth and calculated as a percentage of the yearly minimum wage, categorised by tertiles), and year of entry into the cohort" and "Moreover, in order to understand BFP effects heterogeneity, we fitted these IPTW Poisson regression models stratified by age, sex, race/ethnicity, education, and wealth- tertiles (per capita expenditure)."
Population characteristics	BFP beneficiaries and non-beneficiaries showed similar demographic and socioeconomic characteristics. In comparison with non-beneficiaries, BFP beneficiaries are younger (mean age 24.2 vs 25.3 years), had a slightly higher percentage of people self-identified as Black or Pardo race/ethnicity (62.1% vs 68.7%), people with no education (32.5% vs 37.1%), households with 3 or more individuals (66.0% vs 78.9%), lesser wealth (43.9% vs 58.0%), without adequate sanitation (23.9% vs 38.7%), and without a public network for water supply (70.6% vs 76.1%).
Recruitment	In the Results section: "After excluding individuals of the 100 Million Brazilians Cohort who were outside the study period 2004-2015, and who had missing information on demographic or socioeconomic variables, 54,571,434 individuals were selected, of which 23,907,958 were BFP beneficiaries (43.8%), and 30,663,476 non-BFP beneficiaries (56.2%), with a total of 159,777 new TB diagnoses and 7,993 TB deaths"
Ethics oversight	This study was approved by the Research Ethics Committee of the Institute of Collective Health of the Federal University of Bahia (ISC/UFBA), under number 41691315.0.0000.5030 (Assessment nº:3.783.920)

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

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☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	The entire eligible population was considered, i.e., individuals registered in the Cadastro Único (CADU) between 2004 and 2015, with or without a diagnosis of tuberculosis, whether or not they were beneficiaries of the BFP. From this initial selection, which is a subgroup of the Cohort of 100 Million Brazilians, individuals with less than 1 day of follow-up, diagnosed with TB or who received the BFP before 2004, Individuals with inconsistent dates, duplicates, Individuals who received BFP <30 days and Individuals with missing values for socioeconomic variables were excluded (as described in Figure 1 - Flowchart). After these exclusions, the entire final population was considered for the analysis, i.e., 54,571,434 individuals, being Non-BFP beneficiaries (n=30,663,476) and BFP beneficiaries (n=23,907,958).
Data exclusions	In the Results section: "After excluding individuals of the 100 Million Brazilians Cohort who were outside the study period 2004-2015, and who had missing information on demographic or socioeconomic variables, 54,571,434 individuals were selected, of which 23,907,958 were BFP beneficiaries (43.8%), and 30,663,476 non-BFP beneficiaries (56.2%), with a total of 159,777 new TB diagnoses and 7,993 TB deaths" (as described in Figure 1 - Flowchart).

Replication	We performed several sensitivity and triangulation analyses. All results confirmed the results obtained in the main analysis. Sensitivity and triangulation analyses section: "We developed a wide range of several sensitivity analyses (for details see the Methods section and Supplementary Tables S1-S7) fitting models with differed specifications and adjusting variables. We also performed two different triangulation analyses: Cox multivariate regression and propensity score matching (PSM) (Extended Data Table 4). All sensitivity tests confirmed the association estimates, and the triangulation analyses showed a high degree of confidence in the effect evaluation causal inference."
Randomization	The allocation was not random. In the Data sources, outcomes, and intervention section: "The beneficiary group was defined as eligible individuals who received BFP benefits, and their exposure started with receipt of the benefit, until the end of their follow-up. The non-beneficiary group was defined as individuals who had never benefited from BFP throughout their follow-up period. In case of non-receipt of the benefits, eligible individuals were classified in the non-beneficiary group"
Blinding	The blinding is not relevant to this study because it is not an experimental study. In this study the main exposure was the receipt of BFP and the researcher has this information through an administrative database without the names of the individuals.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Plants

Seed stocks	n/a
Novel plant genotypes	n/a
Authentication	n/a