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Social protection to reduce financial burden of tuberculosis in Timor-Leste (TB-PROTECT): a cluster randomized trial

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Abstract

Background

To evaluate whether a tuberculosis (TB)-specific cash transfer reduces the proportion of households facing catastrophic costs and to assess its effects on treatment success and financial burden in Timor-Leste.

Methods

We conducted a cluster-randomized controlled trial (December 2022–September 2023) across 32 community health centers. Patients aged ≥17 years initiating standard treatment were enrolled. Intervention clusters provided monthly cash transfers (US$ 30) for six months; control clusters provided standard care. The primary outcome was the proportion of households incurring catastrophic costs (≥20% of annual income). Data were collected using modified WHO Patient Cost Surveys. Analyses followed intention-to-treat principles using multivariate regression accounting for clustering.

Results

Among 329 patients enrolled (161 intervention, 168 control), the proportion facing catastrophic costs was significantly lower in the intervention group (58·4%) than in the control group (85·1%; p<0·001; adjusted odds ratio 4.48, 95% CI 1.88-10.68). Indirect costs were reduced by US$237·92 (95% CI 117·68–358·17). No significant differences were observed in non-medical costs or treatment success. No intervention-related adverse events were reported.

Conclusions

Unconditional cash transfers significantly reduced catastrophic costs and indirect financial burden among tuberculosis patients but had no effect on treatment success. To achieve the goal of zero catastrophic costs, multidimensional social protection strategies addressing non-medical costs—including food and transport support—are essential alongside financial assistance.

Trial registration

Clinical Research Information Service of Republic Korea: KCT0009506 (Registered June 5th, 2024).

Background

Tuberculosis (TB) remains one of the leading infectious causes of morbidity and mortality worldwide, disproportionately affecting low- and middle- income countries. In 2024, an estimated 10.7 million people developed TB, and 1.23 million died from the disease, with the largest number of new cases occurring in the World Health Organization (WHO) South-East Asia Region[1]. Beyond its clinical consequences, TB imposes a substantial financial burden on patients and their households, particularly

in resource-limited settings where even modest TB-related expenditures can lead to treatment interruption or nonadherence. In recognition of these intertwined medical and socioeconomic burdens, the WHO established three key goals in its End TB Strategy to be achieved by 2030: a 95% reduction in TB deaths, a 90% reduction in the TB incidence, and zero TB-affected households facing catastrophic costs due to TB[1].

Among the most affected countries is the Democratic Republic of Timor-Leste, classified by the WHO as a high TB burden country. In 2022, the estimated TB incidence in Timor-Leste was 496 per 100,000 population- one of the highest in the Southeast Asian Region[1]. Although TB diagnosis and treatment are provided free of charge through the public health system, patients and their households continue to face substantial financial burdens, particularly from non-medical expenses such as food and nutritional supplements[2], as well as from income loss prolonged treatment. In this context, cash transfers have emerged as a promising approach for reducing financial and economic barriers to care and improving TB-related outcomes, particularly in health systems like that of Timor-Leste[3]. However, despite their potential, rigorous causal evidence assessing the effectiveness of cash transfer programs in TB control remains limited.

To address this evidence gap, this study evaluated the effectiveness of a cash transfer intervention in reducing the financial burden associated with TB in Timor-Leste. Secondary objectives included examining its impact on treatment success rates, mean indirect costs, and mean non-medical costs across intervention and control groups.

Methods

Study designs and participants

A non-blinded, cluster randomized controlled trial was designed and conducted between December 6, 2022, and September 7, 2023. The protocol was registered at Clinical Research Information Service of Republic Korea (registration number: KCT0009506). This study was a component of a five-year project supported by the Korea International Cooperation Agency (KOICA) titled “Capacity Building on Community-based Tuberculosis Diagnosis and Management in Timor-Leste.” The project specifically targeted thirty-two community health centers located in five municipalities: Baucau, Bobonaro, Covalima, Dili, and Ermera. In this study, these health centers were then considered as clusters and randomly allocated to either the intervention or control arm, with an equal number of clusters in each (16 clusters per arm). The cluster-level randomization was chosen primariliy for operational feasiblity, as the cash transfer intervention was integrated into the routine administrative workflow of the health centers. The study employed simple random sampling, during an initiation workshop on November 24, 2022, an independent national TB program coordinator (non-involved in patient recruitment) selected sealed slips of paper from an opaque box to determine the allocation of each cluster.

During the study period, participants who came to the study site and initiated their tuberculosis treatment had an initial eligibility check by TB health workers at health centers. Individuals aged seventeen or older, who initiated TB treatment within one month, and started on the standard six-month regimen (comprising a two-month intensive phase of rifampicin (R), isoniazid (H), pyrazinamide (Z), and ethambutol (E), followed by a four-month continuation phase of rifampicin and isoniazid, abbreviated as 2RHZE/4RH), at the study location, were included in the study. We excluded those who tested positive for drug-resistant tuberculosis, those who opted to start or transition to a second-line drug regimen for clinical reasons, or incarcerated individuals.

Assuming 20% catastrophic costs in the control group[5] and an intracluster correlation coefficient (ICC) of 0.05, we calculated a required sample size of 320 participants (160 per arm) to detect a 20-percentage point reduction with 80% power and a 5% significance level, accounting for a 10% dropout rate[4,5].

Procedures and intervention

We used a modified WHO TB Patient Cost Survey, translated into *Tetum*. Participants were interviewed twice: within one week of enrollment (baseline characteristics and pre-diagnosis costs) and at the end of treatment (follow-up costs and coping mechanisms). Trained interviewers collected clinical outcomes from treatment cards under National TB Program supervision. In intervention clusters, patients received a monthly cash transfer of US$ 30 for six months. Control clusters followed the standard directly observed treatment (DOT) strategy according to national guidelines.

Measurements

The primary outcome was the proportion of households facing catastrophic costs (total costs >20% of annual income). For the intervention group, the actual total cash transfer received by each participant was added to their household income for this calculation. Secondary outcomes included treatment success rates (cured or completed)[7], mean indirect costs (income and time loss), and mean non-medical costs (transport, food, accommodation) [6]. Indirect costs were calculated using both the output approach (income change) and the human capital approach (time loss multiplied by hourly wage) [6].

We further measured several baseline socio-economic and clinical indicators as covariates. Socio-economic indicators included educational attainment, employment conditions, and wealth index. The wealth index was calculated by summing the possession of 15 household assets: electricity, computer, television, refrigerator, air conditioner, electric fan, gas stove, washing machine, vacuum cleaner, microwave, watch, car or truck, radio, mobile phone, and motorcycle. The scores were stratified into four categories: lowest (0–2), lower middle (3–4), upper middle (5), and highest (6–15). Clinical and demographic data included gender, age, type of tuberculosis, treatment institution, tuberculosis history, and HIV status.

Statistical analysis

Analyses were conducted on an intention-to-treat basis. Categorical variables were presented using counts and proportions, while continuous variables were presented using medians and interquartile ranges. Comparisons of categorical variables between arms were performed using the chi-square test. To account for the clustering of participants within health centers, we used multivariate logistic regression with cluster-robust standard errors to investigate the effect of cash transfer on patients experiencing catastrophic cost due to TB after adjusting for age, gender, type of TB, treatment institutions, TB history, educational attainment, employment conditions, and wealth index, with adjusted odds ratios (aORs), adjusted relative risks (aRRs), and adjusted risk differences (aRDs) including 95% confidence intervals presented. Three types of sensitivity analyses were conducted using multivariate logistic regression with cluster adjustment. First, we excluded patients with zero household income at baseline. Secondly, propensity score matching (PSM) was performed using covariates of HIV status and educational attainment. Matches were made within a caliper of 0.01 standard deviations of the logit of the propensity score, with no replacement. Finally, the catastrophic cost threshold was varied to 40% to observe the robustness of the findings. All analyses were conducted using Stata/SE 17 (StataCorp, College Station, TX), R (version 4.3.1) and RStudio (version 2023.12.1 + 402), with a significance level set at p-value < 0.05.

Results

General characteristics of participants

We randomly allocated 32 clusters to receive cash transfer (n.c=16) or management as usual (n.c=16). From the clusters that receive cash transfer, 161 patients participated in the first cost survey and 157 patients completed the second cost survey, 4 patients were lost during the follow-up due to deaths. In the control group, the first cost survey was conducted on 168 patients and the second cost survey on 163 patients, with 2 patients lost to follow-up and 3 patients lost to deaths. In all, 7 deaths occurred during the trial, but the events were not related to the intervention (Fig. 1).

Baseline characteristics were similar between study groups, except for HIV status and educational attainment. The mean age of participants was 49.77 years (SD 18.27). Out of all 329 participants, 303 (92.1%) had their TB diagnosis bacteriologically confirmed, and 26 (7.9%) received only clinical diagnoses. 260 (79.0%) received treatment at health centers, 45 (13.7%) at public hospitals, and 24 (7.3%) at other facilities. 296 (90.0%) had a new case of TB, 30 (9.1%) had a history of a previously treated TB case, and 3 (0.9%) had unknown history with TB. Regarding the observed imbalances, in the control group, 139 (82.7%) were confirmed with negative HIV status, while in the intervention group, 93 (57.8) had negative HIV status. As to educational attainment, 19.1% in the control group vs 35.4% in the intervention group had secondary education or above. When divided into four categories according to our wealth index, 91 (27.7%) were included in the lowest class, 132 (40.1%) in the lower middle class, 59 (17.9%) in the upper middle class, and 47 (14.3%) in the highest class (Table 1). In the pre-diagnosis period, mean household income was US$ 74.75 (SD 126.84, median 30.00, IQR 0.00-100.00) (Table S1). In the intervention group, the mean amount of cash transfer received was US$ 177.58 (SD 16.42).

Table 1. Baseline demographic and clinical characteristics of study participants, Timor-Leste, 2022–2023. IQR: interquartile range; n: number of participants; SD: standard deviation.

Characteristics	Total (n = 329)	Control (n = 168)	Intervention (n = 161)	p-value
Gender, *n* (%)				0.66
Men	186 (56.5)	93 (55.4)	93 (57.8)	
Women	143 (43.5)	75 (44.6)	68 (42.2)	
Age, mean (SD)	49.77 (18.27)	52.83 (17.88)	46.58 (18.19)	
Age, median (IQR)	54 (34-65)	57 (39-66.5)	50 (28-60)	
Age range, *n* (%)				0.06
0-19	13 (4.0)	5 (3.0)	8 (5.0)	
20-29	57 (17.3)	22 (13.1)	35 (21.7)	
30-39	38 (11.6)	15 (8.9)	23 (14.3)	
40-49	32 (9.7)	18 (10.7)	14 (8.7)	
50-59	67 (20.4)	33 (19.6)	34 (21.1)	
60-69	72 (21.9)	44 (26.2)	28 (17.4)	
≥ 70	50 (15.2)	31 (18.5)	19 (11.8)	
Type of tuberculosis, *n* (%)				0.48
Bacteriologically confirmed	303 (92.1)	153 (91.1)	150 (93.2)	
Clinical diagnosis	26 (7.9)	15 (8.9)	11 (6.8)	
Treatment institutions, *n* (%)				0.37
Health center	260 (79.0)	135 (80.4)	125 (77.6)	
Public hospital	45 (13.7)	19 (11.3)	26 (16.2)	
Others	24 (7.3)	14 (8.3)	10 (6.2)	
Tuberculosis history, *n* (%)				0.36
New case	296 (90.0)	155 (92.3)	141 (87.6)	
Previously treated cases	30 (9.1)	12 (7.1)	18 (11.2)	

Characteristics	Total (n = 329)	Control (n = 168)	Intervention (n = 161)	p-value
Unknown history	3 (0.9)	1 (0.6)	2 (1.2)	
HIV status, *n* (%)				< 0.01
Negative	232 (70.5)	139 (82.7)	93 (57.8)	
Not done or unknown	97 (29.5)	29 (17.3)	68 (42.2)	
Educational attainment, *n* (%)				0.00
No education	181 (55.0)	106 (63.1)	75 (46.6)	
Primary education	59 (17.9)	30 (17.9)	29 (18.0)	
Secondary education or above	89 (27.1)	32 (19.1)	57 (35.4)	
Employment condition, *n* (%)				0.11
Unemployment	142 (43.2)	73 (43.5)	69 (42.9)	
Paid work	30 (9.1)	10 (6.0)	20 (12.4)	
Others	157 (47.7)	85 (50.6)	72 (44.7)	
Wealth index, *n* (%)				0.90
Lowest	91 (27.7)	46 (27.4)	45 (28.0)	
Lower middle	132 (40.1)	68 (40.5)	64 (39.8)	
Upper middle	59 (17.9)	32 (19.1)	27 (16.8)	
Highest	47 (14.3)	22 (13.1)	25 (15.5)	

Total mean patient costs calculated using the human capital approach were US$ 656.17 (SD 674.19) in the control group and US$ 330.58 (488.08) in the intervention group (Table 2). When calculated by output approach, they were US$ 779.98 (SD 838.55) and US$ 399.83 (SD 528.25), respectively. The biggest portion of patient costs was accumulated due to food expenses in post-diagnosis period, and it amounted for 48.81% of total costs in the control group and 66.48% in the intervention group. When divided by gender, indirect costs were higher in men, amounting to 6.59% of total costs (output

approach) while in women, they were 0.30% (Table S2). Difference in treatment institutions also influenced indirect costs (Table S3). Patients treated in health centers were the only group that had increased household income when compared to public hospitals and others. According to the wealth index, the lowest class was the only group that benefited from increased household income (mean US$ 61.98, SD 148.46) (Table S4).

Table 2. Mean tuberculosis-related costs per patient by cost category in the intervention and control groups, Timor-Leste, 2022–2023. SD: standard deviation; US$: United States dollars. Note: All costs are expressed in US dollars. Negative values in the intervention group represent a net financial gain where the cash transfer amount exceeded the estimated income loss.

Cost category		Control (n = 168)		Intervention (n = 161)	
		Mean (SD)	%	Mean (SD)	%
Pre-diagnosis	Medical	3.76 (23.80)	0.48	0.01 (0.16)	0.00
	Travel	3.69 (4.19)	0.47	3.70 (5.28)	0.92
	Accommodation	0.51 (2.09)	0.07	0.19 (0.61)	0.05
	Food	2.10 (3.89)	0.27	2.83 (12.65)	0.71
	Nutritional supplements	1.15 (3.57)	0.15	1.19 (3.93)	0.30
Post-diagnosis	Medical	0.11 (1.39)	0.01	0.26 (2.08)	0.07
	Travel	129.31 (94.27)	16.58	113.03 (132.98)	28.27
	Accommodation	33.72 (118.14)	4.32	36.33 (91.21)	9.09
	Food	380.67 (424.19)	48.81	265.80 (257.11)	66.48
	Nutritional supplements	89.54 (223.88)	11.48	69.46 (138.75)	17.37
	Household income loss	135.43 (530.93)	17.36	-92.94 (328.48)	-23.25
	Hours lost by patient and guardian x Hourly wage	11.62 (102.38)		-162.19 (123.93)	
Medical costs		3.86 (23.82)		0.27 (2.09)	
Non-medical costs		640.69 (669.35)		492.51 (454.52)	
Indirect costs	Human capital approach	11.62 (102.38)		-162.19 (123.93)	
	Output approach	135.43 (530.93)		-92.94 (328.48)	
Total	Human capital approach	656.17 (674.19)		330.58 (488.08)	
	Output approach	779.98 (838.55)		399.83 (528.25)	

Primary outcome

The cash transfer significantly reduced the risk of catastrophic costs. Using the human capital approach, 58.4% (94/161) of the intervention group experienced catastrophic costs compared to 85.1% (143/168) of the control group (aOR 4.48; 95% CI 1.88–10.68; $p < 0.001$) (Table 3). Results were consistent using the output approach (aOR 7.97; 95% CI 2.25–28.25). Gender-stratified analysis showed robust protective effects in both groups, though relatively higher in men. The observed ICC was 0.139.

Table 3. Effect of tuberculosis-specific cash transfer on catastrophic costs (primary outcome) by calculation approach and gender, Timor-Leste, 2022–2023. CI: confidence interval. Note: The intervention group served as the reference. Adjusted odds ratios, relative risks, and risk differences were obtained from multivariate logistic regression models adjusted for age, gender, type of tuberculosis, treatment institutions, tuberculosis history, educational attainment, employment conditions, and wealth index, while accounting for the clustering of participants within health centers.

	Odds ratio (95% CI)	Relative risk (95% CI)	Risk difference (%p) (95% CI)
Human capital approach			
Total	4.48 (1.88-10.68)	1.33 (1.04-1.71)	21.23 (12.62-29.83)
Men	7.77 (2.69-22.41)	1.41 (1.07-1.85)	22.83 (13.45-32.22)
Women	3.48 (0.93-13.00)	1.21 (0.93-1.57)	19.14 (10.83-27.44)
Output approach			
Total	7.97 (2.25-28.25)	1.32 (1.05-1.65)	22.09 (14.37-29.81)
Men	13.76 (2.80-67.53)	1.38 (1.08-1.74)	24.32 (15.30-33.33)
Women	14.95 (3.42-65.33)	1.23 (0.96-1.57)	19.20 (11.21-27.18)

Secondary outcomes

Treatment success rates were high and did not differ significantly between groups (96.9% intervention vs 97.0% control; p = 0.369) (Table 4). However, the intervention significantly reduced mean indirect costs compared to the control group (coefficient US$ 237.92; 95% CI 117.68–358.17) (Table 5). The protective effect was consistent across most socioeconomic subgroups, except for the highest wealth index category.

Table 4. Tuberculosis treatment outcomes (secondary outcome) in the intervention and control groups, Timor-Leste, 2022–2023. n: number of participants.

Treatment result	Control		Intervention		p-value
	n	%	n	%	
Treatment success	163	97.02	156	96.89	0.369
Loss to follow-up	2	1.19	0	0.00	
Deaths	3	1.79	4	2.48	
Failure	0	0.00	1	0.62	

Table 5. Secondary outcomes including unfavorable treatment outcomes and mean tuberculosis-related costs, Timor-Leste, 2022–2023. CI: confidence interval. Note: The intervention group served as the reference. Unfavorable treatment outcome refers to the sum of loss to follow-up, deaths, and treatment failure. Odds ratios and coefficients were obtained from multivariate logistic regression models adjusted for age, gender, type of tuberculosis, tuberculosis history, educational attainment, employment conditions, and wealth index, while accounting for the clustering of participants within health centers.

		Odds ratio (95% CI)
Treatment result	Unfavorable outcome	1.48 (0.34-6.56)
		Coefficient (95% CI)
Non-medical cost		98.28 (-15.92-212.48)
Indirect cost		237.92 (117.68-358.17)

Sensitivity analysis

Sensitivity analysis excluding participants who had zero household income at baseline (n=75 in control group, n=54 in intervention group) confirmed that control group had a higher risk of catastrophic costs (human capital approach: aOR 6.69, 95% CI 2.94-15.21) (Table 6). PSM (n=121 per arm) and varying the catastriphic cost threshold to 40% also yielded consistent results, demonstrating the robustness of the primary findings.

Table 6. Sensitivity analyses of the effect of cash transfer on catastrophic costs under different scenarios, Timor-Leste, 2022–2023. CI: confidence interval; HIV: human immunodeficiency virus; PSM: propensity score matching. Note: Sensitivity analyses included (i) excluding households with zero income at baseline to test for income measurement bias, (ii) propensity score matching based on baseline HIV status and educational attainment to address observed imbalances, and (iii) increasing the catastrophic cost threshold to 40% of annual household income to assess the robustness of the protective effect.

	Odds ratio (95% CI)	Relative risk (95% CI)	Risk difference (%p) (95% CI)
Excluding zero household income at baseline (excluded number of control = 75, intervention = 54)			
Human capital approach			
Total	6.21 (2.81-13.73)	1.76 (1.29-2.41)	33.86 (21.23-46.49)
Men	9.43 (3.34-26.66)	1.65 (1.22-2.25)	32.56 (20.39-44.73)
Women	7.35 (0.93-57.96)	1.65 (0.97-2.80)	36.63 (22.75-50.52)
Output approach			
Total	10.07 (3.59-28.28)	1.59 (1.25-2.03)	34.54 (23.23-45.86)
Men	15.84 (3.30-75.93)	1.52 (1.19-1.95)	32.74 (21.66-43.82)
Women	54.36 (3.07-963.91)	1.46 (0.86-2.47)	38.36 (24.11-52.60)
PSM using HIV status and education attainment (control = 121, intervention = 121)			
Human capital approach			
Total	3.91 (1.40-10.88)	1.30 (1.02-1.65)	16.43 (6.86-25.99)
Men	6.62 (1.65-26.49)	1.37 (1.02-1.84)	18.02 (7.31-28.74)
Women	2.68 (0.64-11.24)	1.16 (0.90-1.51)	12.69 (4.77-20.61)
Output approach			
Total	6.16 (1.52-24.98)	1.29 (1.06-1.56)	17.42 (8.71-26.13)
Men	8.96 (2.10-38.27)	1.35 (1.10-1.66)	19.43 (9.29-29.57)
Women	19.40 (2.16-174.05)	1.19 (0.94-1.50)	12.69 (4.87-20.51)
Catastrophic cost cut off: 40%			
Human capital approach			
Total	3.17 (1.29-7.79)	1.33 (1.04-1.71)	18.58 (9.36-27.80)
Men	3.86 (1.27-11.79)	1.41 (1.07-1.85)	19.99 (10.02-29.96)
Women	2.46 (0.73-8.26)	1.21 (0.94-1.57)	16.74 (8.14-25.34)
Output approach			
Total	3.67 (1.48-9.13)	1.32 (1.05-1.65)	19.86 (10.84-28.87)
Men	3.28 (1.13-9.52)	1.38 (1.08-1.74)	22.23 (11.99-32.48)

	Odds ratio (95% CI)	Relative risk (95% CI)	Risk difference (%p) (95% CI)
Women	5.84 (1.73-19.73)	1.23 (0.96-1.57)	16.77 (8.67-24.86)

Discussion

The study identified that TB-specific cash transfers could reduce the proportion of people suffering from catastrophic costs due to TB. The reduction rate was approximately 20%p, and this trend remained consistent in the sensitivity analysis. While the intervention successfully lowered indirect costs by offsetting income loss, it did not significantly alter the total amount of non-medical expenditures or improve treatment success rates. These findings provide critical evidence for the role of social protection in high-burden, low-income settings.

Cash transfers are increasingly recognized as a key social protection tool to reduce financial burden and advance Universal Health Coverage (UHC)[8]. These interventions can be conceptualized along a continuum: TB-specific programs provide target support exclusively to TB-affected individuals or households (e.g., Peru's CRESIPT), and TB-sensitive programs include TB patients within broader vulnerability criteria (e.g., Brazil's Bolsa Familia), and TB-inclusive strategies target structural determinants of TB among high-risk populations through poverty alleviation measures (e.g., South Africa's Temporary Disability Grant)[9,10,11]. Our intervention aligns most closely with a TB-specific approach and demonstrates its capacity to substantially reduce-but not eliminate-financial burden.

The cash transfer was originally targeted to reduce both direct and indirect costs generated from TB management and care, with the aim of subsequently improving treatment outcomes and reducing the risk of additional transmission in the community[3,8]. However, there are few studies examining the economic impact of cash transfers among TB-affected populations. The Peruvian study identified that the cash transfer reduced the proportion of catastrophic costs by 12 percentage points compared to the control group[9], which aligns with our findings, though our study showed a relatively greater benefit. Two modeling studies consistently identified that TB-specific cash transfers could reduce financial suffering among TB households, but both concluded that cash transfers alone could not achieve the global target of zero catastrophic costs[5,10]. While TB diagnosis and treatment are provided free of charge in Timor-Leste, our findings affirm that such services alone are insufficient to protect TB affected households from financial hardship. In this context, where out-of-pocket spending on food and income loss account for most TB-related costs, even with a US$180 cash transfer during the treatment period, approximately 60% of TB households still suffered from catastrophic costs. While cash support helped prevent income loss in the intervention group, non-medical costs remained high, which continued to impose significant financial hardship on about 60% of the intervention group. The findings from our study, along with previous modeling studies, indicate the importance of a multidimensional approach to prevent catastrophic costs due to TB. This approach could include nutritional support, housing assistance, and transportation subsidies alongside cash transfers, addressing the broader spectrum of non-medical costs and reducing the overall financial burden more effectively.

Previous studies have demonstrated the benefits of cash transfers in improving tuberculosis (TB) treatment outcomes[11-14]. However, our study did not show a positive impact of cash transfers on treatment outcomes. Notably, there were no patients lost to follow-up (LTFU) in the intervention group, while two patients were LTFU in the control group. The primary reason for the lack of observed positive impact on treatment outcomes in our study is the relatively high treatment success rates (TSRs) in Timor-Leste. According to WHO data, the TSR in Timor-Leste has exceeded 92% since 2019[1]. In our study, the TSRs in both the intervention and control groups were similarly high at 97%, which is higher than previous notification data. The differences in TSRs compared to routine data are due to slightly higher LTFU and fatality rates in routine data than in our study outcomes. Consequently, the high TSRs in both study groups obscured the identification of any positive impact. Given the context of high TSRs and the high proportion of zero household income (83.28% among all participants at baseline) in Timor-Leste, cash transfers should be considered a strategy to reduce catastrophic costs rather than a means to improve TSR itself.

The study was conducted in a lower-middle-income country as classified by the World Bank and ranked 155th on the Human Development Index by the United Nations Development Program[15]. When considering the generalizability of the study outcomes, these contextual factors must be carefully considered. The first patient cost survey of tuberculosis in Timor-Leste identified that approximately 80% of patients faced catastrophic costs[16]. In response, the National Tuberculosis Program (NTP) of Timor-Leste expanded Directly Observed Treatment (DOT) coverage to reduce direct medical costs. This effort likely contributed to the almost zero direct medical costs observed in our study. However, significant financial burdens remained, including high costs for food (48.81%), income loss (17.36%), and nutritional supplements (11.48%). The latest Labor Force Survey in Timor-Leste identified that about 77.3% of the population worked in informal sectors, with an average monthly salary of approximately 248 USD for employees and 142 USD for the self-employed[17]. Therefore, cash transfers might serve as a fundamental resource for maintaining livelihoods among TB-affected households. One of the secondary outcomes of the study was the examination of the interaction between cash transfers and socioeconomic positions. The study found no significant interactions, except for a synergistic effect among paid workers (aOR: 25.25, 95% CI: 1.96-325.09). The minimal interaction between the intervention and socioeconomic positions suggests that cash transfers could be effectively used as a basic livelihood source during the TB treatment period. Thus, the role of cash transfers in this context should be considered when designing and developing new or additional social protection schemes in low-income countries. Furthermore, cash transfer programs may yield differential health and economic impacts depending on recipients' socioeconomic position, even when the same amount is provided to all. Prior research has shown greater benefits among lower-income groups, highlighting the limitations of a uniform approach and the value of proportionate universalism—where the scale of support is adjusted according to need[18]. Future social protection programs should therefore consider adopting proportionate universalism to reduce inequities and protect the most vulnerable more effectively.

The study has some limitations. First, while simple cluster randomization was used, a few baseline characteristics differed between the groups. However, sensitivity analyses using PSM conformed that our primary findings remained robust after adjusting for these factors. Second, the non-blinded nature of the intervention may have introduced social desirability bias in self-reported costs, though the use of independent trained interviewers was intended to mitigate this risk. Third, the observed ICC for the primary outcome was higher than the anticipated ICC used for sample size calculation, potentially reducing statistica power of subgroup analyses. However, the primary results remained highly significant, suggesting the effect size of the intervention was sufficient to overcome the increased design effect. Finally, the study measured treatment success rate as a relatively short-term outcome and could not assess long-term consequences such as TB relapse or post-TB complications.

Conclusions

This cluster randomized controlled trial demonstrates that TB-specific cash transfers can significantly reduce the risk of catastrophic costs among TB-affected households in Timor-Leste, particularly by mitigating indirect costs. Although already high treatment success rates were not further improved, the intervention provided essential financial protection across various socioeconomic groups. To achieve the End TB goal of zero catastrophic costs, future policies should combine cash transfers with complementary support measures and adopt proportionate approaches tailored to household vulnerability.

Declarations

Human ethics and consent to participate

The study design was approved by ethical review committees at the Institutional Review Board of the Korean National Tuberculosis Association (reference number 2022-KNTA-IRB-03) and the Institute National of Public Health Timor-Leste - Research Ethics & Technical Committee (reference number 2049 MS-INS/DE/X/2022). All participants provided written informed consent before the initial interview with the WHO patient cost survey questionnaire.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the Zenodo repository, https://doi.org/10.5281/zenodo.19048697.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HC and CL conceptualized the study and developed the research design. JS and MY performed the statistical analyses and drafted the initial manuscript. JCJ coordinated the field implementation and supervised data collection in Timor-Leste. SHO, YC, HJK, and HJL were responsible for project management, monitoring, and quality control. HS and HC provided high-level supervision and critical interpretation of the data. All authors critically revised the manuscript for important intellectual content and approved the final version for publication.

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Figures

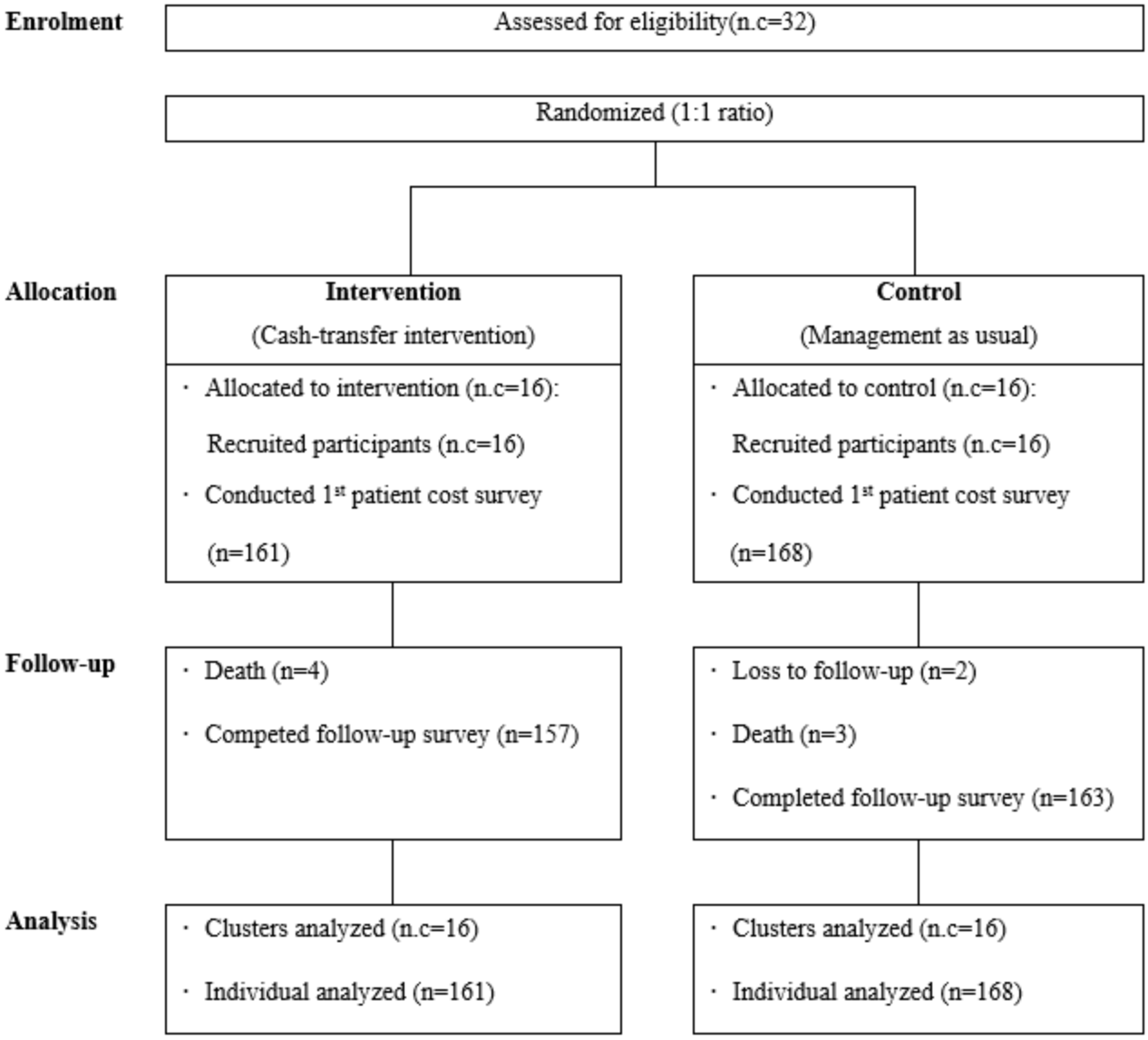


Figure 1

Flow of clusters and participants through the study.n.c=number of clusters; n=number of participants

Supplementary Files

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