Tuberculosis case detection by trained inmate peer educators in a resource-limited prison setting in Ethiopia: a cluster-randomised trial

Kelemework Adane, Mark Spigt, Bjorn Winkens, Geert-Jan Dinant

Summary

Background To improve tuberculosis case detection, interventions that are feasible with available resources are needed. We investigated whether involving trained prison inmates in a tuberculosis control programme improved tuberculosis case detection, shortened pre-treatment symptom duration, and increased treatment success in a resource-limited prison setting in Ethiopia.

Methods In this cluster-randomised trial we randomly assigned prisons in the regions Amhara and Tigray of Ethiopia to an intervention group or a control group, after matching them into pairs based on their geographical proximity and size. Larger prisons were considered eligible whereas smaller prisons were excluded. We selected three to six prison inmates in each intervention prison. The recruited prison inmates who received a 3-day training course and were capable of identifying presumptive tuberculosis cases then provided health education to all other prison inmates about tuberculosis prevention and control every 2 weeks for 1 year. They also actively searched for symptomatic prison inmates and undertook routine symptom-based tuberculosis screening. The control prisons followed the existing passive case finding system. The primary outcome was the mean case detection rate at the end of the year, measured at cluster (prison) level. This trial is registered at ClinicalTrials.gov, number NCT02744521.

Findings We randomly assigned 16 prisons with a total population of 18 032 inmates to either the intervention group (n=8) or the control group (n=8) from April 1, 2016, to March 31, 2017. During the 1-year study period, 75 new tuberculosis cases (1% of 8874 total inmates) were detected in the intervention prisons and 25 new cases (<1% of 9158 total inmates) were detected in the control prisons. The mean case detection rate was significantly higher in the intervention group than in the control group (mean difference 52·9 percentage points, 95% CI 17·5–88·3, p=0·010).

Interpretation Involving trained inmate peer educators in the tuberculosis control programme in Ethiopian prisons significantly improved the tuberculosis case detection rate. The findings have important implications for clinical and public health policy, particularly in prisons of low-income countries where tuberculosis burden is high and the recommended tuberculosis diagnostic and treatment algorithms have generally not been implemented.

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Introduction

With an estimated yearly 10·4 million new cases worldwide and 1·4 million deaths, tuberculosis still represents a large burden, especially for the poorest people.[1] Major obstacles in the global fight against tuberculosis are missed tuberculosis cases and failures to detect the disease early. Each year more than 3 million active tuberculosis cases are missed by health-care systems (either they remain undiagnosed or are diagnosed but not reported).[1] As a consequence, undiagnosed cases remain a source of onward transmission of the disease. Many undetected cases occur in overlooked but high-risk settings such as prisons.[2] Particularly, the prisons in sub-Saharan African are known to be affected by undetected tuberculosis. Studies from some of the countries in the region indicate that 0·5–7·6% of prison inmates have undiagnosed but active tuberculosis, constituting a large source of tuberculosis transmission not only for other prison inmates but also for the general population.[3–5] A systematic review of published studies[6] reported about a 4-fold higher prevalence (888 per 100 000 prison population) of tuberculosis in Ethiopian prisons than the national average (277 per 100 000 population).[7] The emergence of multidrug-resistant tuberculosis adds to the problem, as shown by a study in Zambian and Ethiopian prisons in which up to 9·5% of tuberculosis cases were multidrug-resistant.[8,9] In some of these prisons, 50% of overall deaths were caused by tuberculosis.[10]

The focus on the directly observed treatment short course (DOTS) approach without active case finding is proving to be insufficient to end the tuberculosis epidemic.[11] Use of systematic screening through an entry and exit screening and frequent mass screening using a combination of screening and diagnostic tools (usually sputum smear microscopy and chest X-ray) seems needed and has improved tuberculosis case finding in prisons.[12]

Research in context

Evidence before this study

We searched PubMed for relevant articles published in English up to March 1, 2017, using the terms "tuberculosis and enhanced case finding" and "peer education and prisons". We identified two other studies related to tuberculosis case finding in prisons: a pre-post interventional study in Indian prisons and a qualitative study in Zambian prisons. The study in India showed an increase in tuberculosis case finding through regular educational mobilisation of prison inmates by prison authorities and health staff. The study in Zambia reported that trained inmate peer educators successfully facilitated tuberculosis screening and supported treatment adherence for their fellow prison inmates. However, no trial has been published assessing the effect of peer education on tuberculosis control in prisons.

Added value of this study

This is the first trial of a public health intervention in this subject area which involves the prisoners themselves instead of the health professionals. The study shows that tuberculosis case detection in resource-limited prisons could substantially improve if the prisoners themselves were taking part in the tuberculosis control programme. Very little financial support would be necessary to train the prisoners, with voluntary supervision done by prison health professionals. Our findings add value to existing evidence because the study was done in neglected populations with high tuberculosis burden who need improvements in case finding is most urgently.

Implications of all the available evidence

Earlier tuberculosis case detection with improved access to treatment, including in high-risk settings such as prisons, is a key objective of the WHO End TB Strategy. Previous evidence suggests that active case finding in addition to an entry and exit screening and frequent mass screening substantially improves case finding in prisons, and has been applied in prisons of high-income countries. However, shortage of trained health-care workers and resource scarcity limits the use of such a diagnostic algorithm in the prisons of low-income countries. In such resource-limited, high-risk settings, national tuberculosis control programmes should not only focus on adapting and introducing better screening and diagnostic tools, but should also give priority to potentially more feasible and sustainable public health interventions like those suggested in our study.

However, resource scarcity and a shortage of health personnel limit the applicability of systematic screening in prisons of poor countries.[13] We therefore need alternative methods to improve access to such diagnostic services and increase case finding in prisons. Community-based active case-finding interventions that include improved access to health care have shown an increase in tuberculosis case detection and treatment success in different regions with high burden of tuberculosis.[14,15] In prisons, a pre-post interventional study from India suggested an increase in tuberculosis case finding through the use of regular educational mobilisation by prison authorities and prison health staff.[16] However, the approach requires trained staff and should be tested with an experimental design before being scaled up and adapted.

The use of peer education to train prison inmates on health-related issues could be a very cost-effective alternative, and has already been shown to improve HIV screening and prevention in prisons.[17,18] However, to our knowledge peer education as a model to fight tuberculosis in prisons is not practiced on a wide scale and no published trials investigating the potential outcome of such a programme have been published. In this study we assessed whether empowering and involving prison inmates in tuberculosis control improves tuberculosis case detection in a resource-limited prison setting.

Methods

Study design and participants

In this cluster-randomised controlled trial we randomly assigned prisons in two large regions in Ethiopia to either an intervention group or a control group over a 1-year period. Prisons in the regions Amhara and Tigray were assessed for eligibility; larger prisons were considered to be eligible whereas smaller prisons were excluded. Larger prisons were defined as institutions that incarcerate people for longer periods (ie, many years) while smaller prisons were defined as institutions that incarcerate people for shorter periods. The prisons were then matched into pairs on the basis of their geographical proximity and size.

The ethical review committee of Mekelle University approved the study protocol. All participants who received screening or were involved in the knowledge, attitude, and practice (KAP) survey provided written informed consent.

Randomisation and masking

The prisons included in the study were randomly allocated (1:1) to the intervention or control group. One of the investigators (MS) who did not have knowledge of the characteristics of the prisons randomised the prisons to the intervention or control group using a randomisation website (random.org). The physicians and laboratory professionals involved in the tuberculosis diagnosis and those assessing the outcomes and interventions were masked to group assignment. However, it was not possible to mask the supervisors and trained prisoners.

Procedures

After a brief discussion with the prison staff about the objectives and procedures of the intervention, we recruited inmate peer educators for each prison in consultation with the prison staff. The following criteria

were used for selection of peer educators: previous experience in coordinating health issues (priority was given to those involved in tuberculosis or HIV control activities), a reasonable level of education (10th grade or higher, priority was given to health professionals), display of good behaviour (as witnessed by the prison health professionals), and length of stay in the prison of at least 12 months. We selected three to six prison inmates in each prison. The recruited prison inmates received a 3-day training course about the cause, transmission, symptoms, diagnosis, prevention, and treatment of tuberculosis and consequences of non-adherence to tuberculosis treatment (training material in appendix). We also briefly trained them about symptom-based tuberculosis screening, identification of presumptive tuberculosis cases, and support of patients with tuberculosis to improve adherence to the tuberculosis treatment. Additionally, we provided them with brochures and posters illustrating the cause, transmission, symptoms, and treatment of tuberculosis.

After the training but before trained prison inmates (peer educators) started their activities, they were assessed for their capability to perform the desired activity (screening and education). We assessed whether they were capable of identifying presumptive tuberculosis cases by providing them simulated presumptive tuberculosis and non-presumptive tuberculosis cases and verifying their conclusions using a checklist. Peer educators that passed the assessment criteria then organised inmates into groups and provided education about tuberculosis, its prevention, control, and its relation with HIV every 2 weeks for 1 year. Peer educators were assigned to specific blocks or rooms in the prisons with monthly rotations. Each time, they did a campaign and gathered the prison inmates either in an open field in the prison compound or in halls. The peer educators then delivered education about tuberculosis to the large group using audio devices. For those who could not gather in large groups for security reasons, peer educators provided the education by organising small groups in the rooms they had been assigned to. If they were not providing tuberculosis education, peer educators actively searched for symptomatic prison inmates and undertook routine symptom-based tuberculosis screening using a standardised tuberculosis screening protocol. They also screened new entrants upon arrival in the prisons.

Prison inmates who had a cough for 2 or more weeks (or for any duration if HIV positive) with or without other symptoms (according to national guidelines)[19] were considered presumptive tuberculosis cases and were linked to the prison health professionals for a referral to the hospitals. On occasion, peer educators took the screened prison inmates with presumptive tuberculosis directly to the responsible prison health professionals and insisted for an immediate referral. The prison health professionals then referred screened prison inmates to nearby hospitals (once or twice in a week depending on the number of cases). Vehicles from the prisons were used to transport the inmates in small groups and the prison guards accompanied each hospital visit as part of their daily responsibilities. At the hospitals, the referred prison inmates followed routine patient management procedures to get a diagnosis. All hospitals follow the national tuberculosis diagnosis and treatment algorithm (figure 1),[19] which relies on direct smear microscopy and chest X-ray. The criteria for smear-negative diagnoses were based on physicians' judgment using the evidence from the X-ray and empirical treatment.

See Online for appendix

After the investigation, the referred prison inmates received medicines as needed (anti-tuberculosis drugs, broad-spectrum antimicrobials or other drugs depending on the diagnosis made) and returned to the prisons. The entire process (from referral to diagnosis and treatment) took 2–3 working days on average. Subsequently, the prison health professionals collected the tuberculosis drugs weekly from the hospitals or nearby health facilities and the patients continued their treatment within the prisons according to national guidelines.[19] The peer educators routinely followed up patients and encouraged them to adhere to the prescribed tuberculosis treatment, and provided education on treatment adherence. Bacteriological follow-up examinations were done at the hospitals according to national guidelines and the peer educators facilitated the referral for checkups as well. The peer educators also followed up those prisons inmates receiving empirical antibiotic treatment, and rescreened and facilitated a re-referral if they did not improve within 2 weeks.

To incentivise the peer educators, we paid them 150 Ethiopian birr (about US$5·50) per month. There were also other motivations for the peer educators such as the desire to support others, the promise to receive a certificate of recognition, and increased opportunities for parole (as promised by the concerned bodies). Prison health professionals assigned to the intervention prisons regularly followed the intervention progress and kept an eye on the daily activities of the peer educators.

The control sites followed the existing passive case finding system (self-referral to nearby hospitals, which use the same guidelines as the hospitals treating patients from intervention prisons). However, we provided them with a standardised up-to-date referral protocol that was also used in the intervention sites. Prison health professionals in the control sites were also informed about the aim of the study and the intervention, and followed the ongoing routine activities that were part of the passive case finding system with equal frequency as peer educators organised activities at the intervention sites. To control possible contaminations, the principal investigator (KA) supervised all activities closely through regular visits and phone calls to intervention and control prisons.

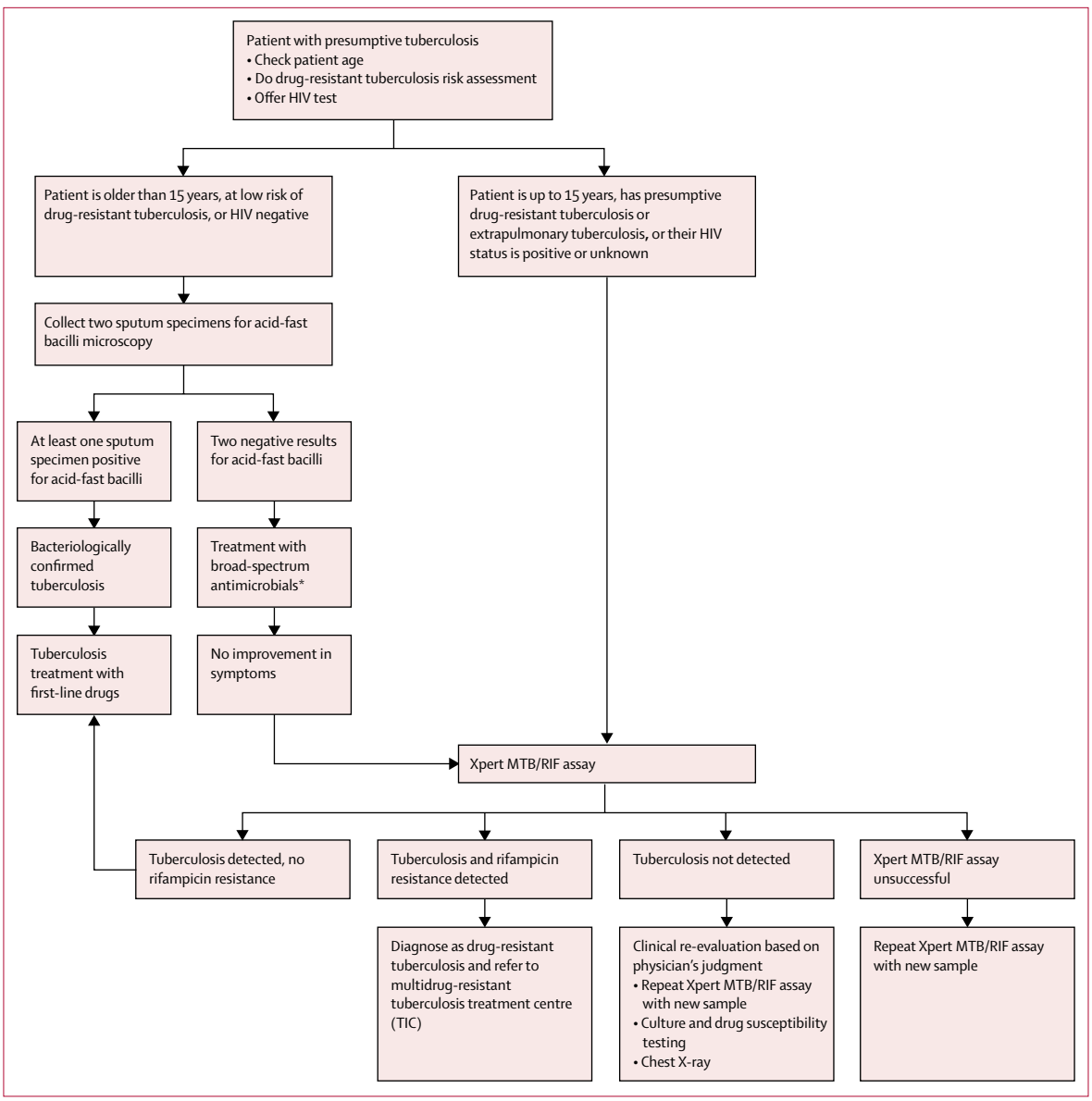

Figure 1: **The national Ethiopian algorithm[19] for tuberculosis diagnosis and treatment**
Presumptive tuberculosis is defined as having signs and symptoms consistent with tuberculosis, mainly a cough of two or more weeks or a cough of any duration if HIV positive. Presumptive drug-resistant tuberculosis is defined as having a previous history of tuberculosis treatment or a contact history with a patient presumed to have drug-resistant tuberculosis. *Broad-spectrum antimicrobials (excluding fluoroquinolone and tuberculosis drugs) are to be given for 10–14 days.

Sociodemographic and clinical characteristics of prisoners with confirmed tuberculosis (eg, age, sex, and pre-treatment symptom duration) were collected in both groups. Baseline data were recorded from the DOTS centres of each prison.

Outcomes

The main aim of the study was to improve tuberculosis detection in the intervention group during the 1-year follow-up period. The primary outcome was the mean tuberculosis case detection rate, expressed as a percentage. The case detection rate was defined as the number of tuberculosis cases detected divided by the estimated number of incident tuberculosis cases per year. The number of incident tuberculosis cases per year was estimated by considering the 2016 WHO estimate of tuberculosis burden for Ethiopia[1] and attributing a fourfold increase in tuberculosis burden to prisons (as illustrated in our 2016 prevalence survey).[3] The number of tuberculosis cases detected was initially estimated from the unpublished review of a two-year DOTS record in some study prisons,[3] but then later it was measured using data from this study. Secondary outcomes were mean treatment success (expressed as a percentage) and

mean pre-treatment symptom duration. Treatment success was defined as the proportion of prisoners with confirmed tuberculosis who were cured (smear-negative or culture-negative in the last month of treatment and on at least one previous occasion) and who completed treatment (finished the treatment with resolution of symptoms but without smear or culture result). The pre-treatment symptom duration (time from symptom onset to treatment initiation) was measured as the duration of coughing in days.

An additional outcome measure was the score obtained by prisoners who took the KAP survey. A sample of prison inmates were randomly selected (with proportional allocation to the total number of inmates in each prison) and data were collected using a standardised semi-structured questionnaire that had been pre-tested by the investigators. KAP was assessed at the end of the study period in both the intervention and control groups. KAP outcome variables were defined taking into account certain basic elements about tuberculosis virulence and spread.

Statistical analysis

We calculated the target sample size accounting for the between-cluster variation, anticipated effect size, and cluster size with a formula suggested by Hayes and Bennett[20] for pair-matched cluster-randomised trials of unequal cluster size:

$$C=2+(Z_{\alpha/2}+Z_{\beta})^2\,[X_0*\mathrm{Av}\left(\frac{1}{n_{0j}}\right)+X_1*\mathrm{Av}\left(\frac{1}{n_{1j}}\right)+k^2(X_0^2+X_1^2)]\,/\,X_0-X_1)^2$$

In this formula, $Z_{\alpha/2}$ and Z_{β} are the standard normal values corresponding to a level of significance α of 0·05 (Z_0·975=1·96) and a power of 80% (Z_0·80=0·84); X_0 is the estimated average annual pulmonary tuberculosis CDR in the control sites (X_0=40%); X_1 is the average annual pulmonary tuberculosis CDR expected in the intervention sites (assuming a 50% increase, it would be 60%); k is the coefficient of variation (k=0·25); the function $\mathrm{Av}(1/n_{0j})$ is the mean of the reciprocals of the cluster sizes (person-years) in the control group ($\mathrm{Av}(1/n_{0j})$=0·001); and $\mathrm{Av}(1/n_{1j})$ is the mean of the reciprocals of the cluster sizes (person-years) in the intervention group ($\mathrm{Av}(1/n_{1j})$=0·0014). Substituting these values in the formula, the computation provided 8·6 pairs and we included 8 pairs in the study considering feasibility. Additionally, we calculated the sample size for the KAP survey with the following formula, considering individual-level randomisation:[20]

$$n=(Z_{\alpha/2}+Z_{\beta})^2\,[X_0*(1-X_0)+X_1(1-X_1)]\,/\,(X_0-X_1)^2$$

Prisoners were categorised as having either good knowledge or poor knowledge depending on the number of survey items mentioned. $Z_{\alpha/2}$ and Z_{β} are the standard normal values corresponding to a level of significance α of 0·05 (Z_0·975=1·96) and a power of 80% (Z_0·80=0·84); X_0 is the estimated mean proportion of good knowledge at baseline (X_0=22%); and X_1 (33%) is the estimated mean proportion of good knowledge after the intervention, considering a 50% increase. Substituting these values and multiplying by 1·5 to account for the clustering effect, the final sample size was fixed to be 631 prisoners for each group.

Data were entered in EpiData (version 3.1; Odense, Denmark) and analysed using IBM SPSS Statistics for Windows (version 20.0; Armonk, NY, USA). Numerical data were presented as means (SD), and categorical data were presented as frequencies (%). Differences in demographic and clinical characteristics between pre-sumptive tuberculosis and active tuberculosis cases in the intervention and control prisons were assessed using χ^2 test for categorical variables and independent samples t test for numerical variables.

	Intervention group (n=8874)	Control group (n=9158)
Number of prisons	8	8
Sex		
Male	8651 (97%)	8944 (98%)
Female	223 (3%)	214 (2%)
Mean cluster size	1109 (694)	1144 (547)
Average floor space per prisoner (m^2)	1·3	0·7
Baseline case notification rate (per 10^5 person-years)	574	481

Data are n, n (%), or mean (SD).

Table 1: **Baseline characteristics of the prisons and study population**

	Intervention group (n=8874)	Control group (n=9158)	p value
Prisoners with presumptive tuberculosis (n=1124)	899 (10%)	225 (2%)	
Mean age	32 (13)	35 (14)	0·003
Sex			<0·0001
Male	889/899 (99%)	213/225 (95%)	
Female	10/899 (1%)	12/225 (4%)	
Prisoners with confirmed tuberculosis (n=100)	75 (75%)	25 (25%)	
Mean age	30 (12)	34 (13)	0·120
Sex			0·014
Male	74/75 (99%)	23/25 (92%)	
Female	1/75 (1%)	2/25 (8%)	
HIV status			
Positive	4/60 (7%)	4/19 (21%)	0·090
Unknown	15/75 (20%)	6/25 (24%)	0·050

Data are n (%) or mean (SD). P values for mean age were calculated with independent samples t test. p values for sex and HIV status were calculates with χ^2 test. Although we are only showing the HIV result of confirmed HIV cases, HIV testing is done for all presumptive tuberculosis cases according to national guidelines.

Table 2: **Demographic and clinical characteristics of prisoners with presumptive tuberculosis and confirmed tuberculosis**

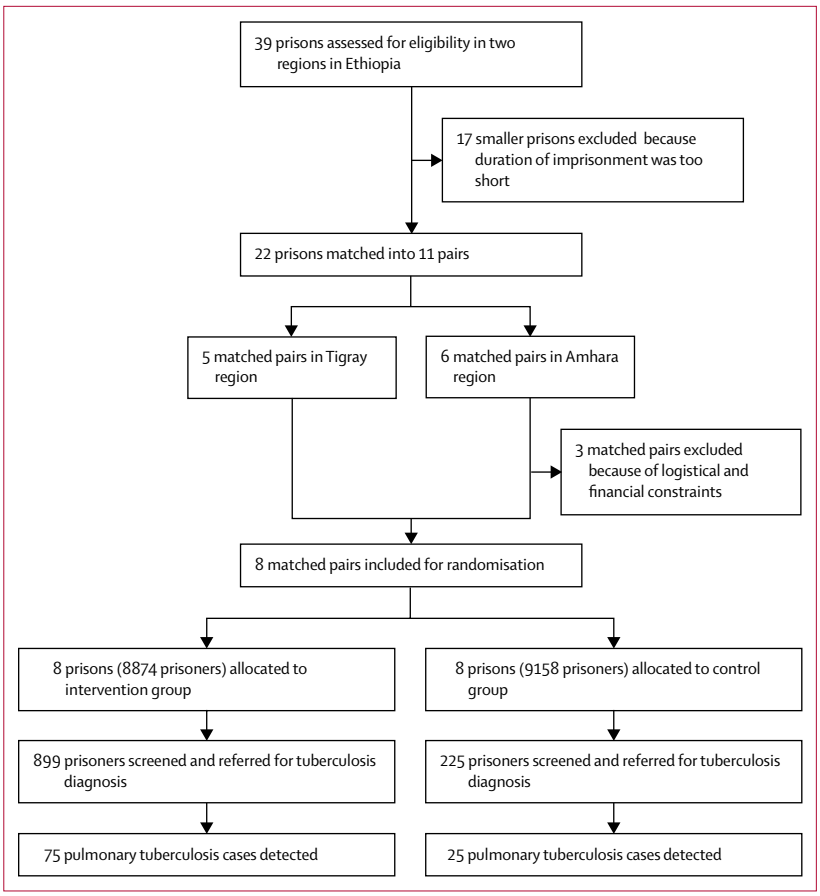

Figure 2: **Trial profile**

	Intervention group (n=75)	Control group (n=25)	Mean difference (95% CI)	p value
Mean case detection rate	79·8% (48·3)	26·9% (13·7)	52·9 (17·5–88·3)	0·010*
Mean treatment success	98·4% (4·6)	97·5% (7·1)	0·88 (–6·6 to 8·4)	0·791
Mean pre-treatment symptom duration (days)	35 (23)	40 (35)	–8·6 (–30·8 to 13·6)	0·404†

Data are n% (SD), n (SD), or percentage point (95% CI). *p=0·018 in the Wilcoxon signed-rank test. †Intraclass correlation coefficient=0·257.

Table 3: **Case detection rate, treatment success rate, and pre-treatment symptom duration of patients with pulmonary tuberculosis (n=100) in Ethiopian prisons after 12 months follow-up**

We assessed the case detection rate and treatment success for each prison using the paired-samples *t* test, and used the Wilcoxon signed-rank test as sensitivity analysis. The pre-treatment symptom duration was measured considering patients as a unit of analysis. We assessed the significance of the mean difference in pre-treatment symptom duration between intervention and control groups using a linear mixed model, taking into account the clustering of patients in prisons. To verify the robustness of the linear mixed model, we also did a sensitivity analysis by applying the same model to the data after logarithmic transformation of the pre-treatment symptom duration.

We used the generalised estimating equation to assess differences in case notification rates (expressed as all cases detected and notified per 100 000 person-years) and KAP scores between intervention and control groups. Group effects were expressed as adjusted odds ratios (ORs) with 95% CIs. The pre-treatment symptom duration was adjusted for cluster size and region, and the case notification rate was adjusted for the baseline case notification rate in addition to cluster size and region. Overall KAP scores were adjusted for cluster size, region, and educational level. Multicollinearity among the independent variables was assessed, with a variance inflation factor greater than 10 indicating a multicollinearity problem. Two-sided p values of at least 0·05 were considered statistically significant. The trial is registered at ClinicalTrials.gov, number NCT02744521.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

39 prisons were assessed for eligibility. 22 larger prisons were considered to be eligible but 17 smaller prisons were excluded. The 22 prisons were matched into pairs based on their geographical proximity and size (11 matched pairs, five in Tigray and the remaining in Amhara). Following matching of prisons into pairs, we randomly assigned eight prisons to an intervention group and eight to a control group over a 1-year period from April 1, 2016, to March 31, 2017. We included all five matched prison pairs from Tigray for the randomisation, considering their proximity to our research department and feasibility. We randomly selected three matched prison pairs from Amhara, considering their increased distance from our research department and the greater logistical and financial difficulties this would bring. We considered the following prison pairs for the randomisation: Mekelle versus Shire, Adawa versus Abi Addi, Humera versus Adigrat, Maichew versus Alamata, Wukro versus Axum, Dessie versus Woldia, Fenote Selam versus Debre Markos, and Debre Tabor versus Bahir Dar.

Table 1 shows the baseline characteristics of the prisons and study population for the two groups. The mean cluster sizes in the two study groups were similar, but the baseline case notification rate was slightly higher in the intervention prisons compared with the control prisons.

During the 1-year study period, we examined a total of 1124 presumptive tuberculosis cases across 16 prisons (n=18 032). The proportion of the prison population examined for presumptive tuberculosis was five times

higher in the intervention group than in the control group (899 [10%] in the intervention prisons *vs* 225 [2%] in the control prisons; table 2; figure 2). Of the 1124 presumptive tuberculosis cases, 75 (7%) were confirmed in the intervention prisons and 25 (2%) were confirmed in the control prisons. 46 (61%) of 75 confirmed cases in the intervention prisons and eight (32%) of 25 confirmed cases in the control prisons were smear negative. Two (3%) cases in the intervention prisons and one (4%) in the control prisons were positive for *Mycobacterium tuberculosis* with the Xpert MTB/RIF assay but were susceptible to rifampicin.

The demographic and clinical characteristics of the prisoners with presumptive and confirmed tuberculosis were similar between the two study groups.

The mean case detection rate was significantly higher in the intervention prisons than in the control prisons (79·8% [SD 48·3] *vs* 26·9% [13·7]; mean difference 52·9 percentage points, 95% CI 17·5–88·3, p=0·010; table 3). Additionally, the mean pre-treatment symptom duration was shortened by 8·6 days in the intervention prisons although this result was not significant (p=0·404). After a log-transformation of pre-treatment symptom duration, this difference remained not significant (p=0·589). Treatment success was high for both groups, but was not significantly different between groups (98·4% for intervention prisons *vs* 97·5% for control prisons, p=0·791).

The overall case notification rate was 0·8% (800 per 100 000 person-years) in the intervention groups and 0·3% (300 per 100 000 person-years) in the control groups. Prison inmates in the intervention group had 1·633 times higher odds of being diagnosed with tuberculosis compared with those in the control prisons (adjusted OR 1·633, 95% CI 1·630–1·636, p<0·0001; table 4). The case notification rate was significantly increased in Tigray prisons compared with Amhara prisons (adjusted OR 1·314, 1·312–1·316, p<0·0001). The odds of finding tuberculosis cases also increased with an increasing baseline case notification rate (adjusted OR 1·239, 1·238–1·240, p<0·001) but decreased with an increasing cluster size (adjusted OR 0·976, 95% CI 0·976–0·977, p<0·0001).

Trends in tuberculosis case detection over the one-year study period were consistently higher in the intervention prisons compared with the control prisons (figure 3).

Several elements of the KAP survey were significantly different among randomly selected prison inmates in both study groups. The proportion of prison inmates who recognised the real cause of tuberculosis, knew that free treatment was available, and mentioned visiting a health-care facility for tuberculosis symptoms at the earliest time possible, was significantly higher in the intervention prisons compared with the control prisons (table 5). There were significant improvements in overall knowledge (p<0·0001) and good practice (p=0·003) in the intervention prisons compared with the control prisons. The differences remained significant after adjustment for educational level, region, and cluster size in a GEE model (adjusted OR 2·54, 95% CI 1·93–3·94 for good knowledge, and adjusted OR 1·84, 1·17–2·96 for good practice). However, there was no significant difference in favourable attitude between of the two groups (adjusted OR 0·80, 0·52–1·25).

	Adjusted odds ratio (95% CI)	p value
Study group		
Intervention group versus control group	1·633 (1·630–1·636)	<0·0001
Region		
Tigray versus Amhara	1·314 (1·312–1·316)	<0·0001
Baseline case notification rate	1·239 (1·238–1·240)*	<0·0001
Cluster size	0·976 (0·976–0·977)†	<0·0001

The odds ratio was adjusted for region, baseline case notification rate, and cluster size. *Odds ratio for every 50 increase in baseline case notification rate. †Odds ratio for every 500 increase in cluster size.

Table 4: **Effect of educational and screening interventions, baseline case notification rate, and cluster size on tuberculosis case finding in Ethiopian prisons**

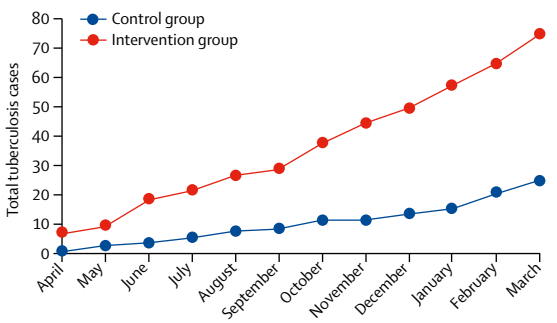

Figure 3: **Trends in tuberculosis case detection in Ethiopian prisons over the one-year intervention period**

Discussion

To our knowledge, this study is one of the few trials done in prisons to investigate the effect of trained inmate peer educators on important health outcomes among prison inmates. We have shown that involving trained prison inmates in tuberculosis awareness and symptom-based screening significantly improved tuberculosis case detection rate. Additionally, the pre-treatment symptom duration was shortened by 8·6 days on average, although this difference was not significant. We also did not find a significant difference in treatment success between groups, but it was high for both groups.

A pre-post interventional study in Indian prisons showed an increase in tuberculosis case finding through regular educational mobilisation of prison inmates by prison authorities and health staff.[16] Moreover, a qualitative study from Zambian prisons reported that trained

	Intervention group (n=601)	Control group (n=617)	p value
Knowledge			
Germs or bacteria cause tuberculosis	368 (61%)	216 (35%)	<0·0001
Tuberculosis is transmitted through cough droplets	571 (95%)	555 (90%)	0·227
Coughing for two or more weeks might be a symptom of tuberculosis	549 (91%)	519 (84%)	0·359
Covering mouth when coughing or sneezing prevents tuberculosis transmission	525 (87%)	527 (85%)	0·951
Free tuberculosis treatment is available	511 (85%)	408 (66%)	0·001
Attitude			
Perceives tuberculosis as a very serious disease	477 (79%)	531 (86%)	0·095
Visits health facility for tuberculosis symptoms	403 (67%)	388 (63%)	0·594
Feels compassion and a desire to help patients with tuberculosis	417 (69%)	389 (58%)	0·324
Practice			
Prefers to visit modern health-care facilities	581 (96%)	588 (95%)	0·838
Visits health-care facility as soon as tuberculosis-related symptoms are discovered	420 (70%)	342 (55%)	0·005
Overall score			
Good knowledge	275 (46%)	155 (23%)	<0·0001
Favourable attitude	225 (37%)	227 (34%)	0·887
Good practice	410 (68%)	330 (49%)	0·003

Prisoners had good knowledge if they mentioned all five items of the knowledge questionnaire. Prisoners had a favourable attitude if they mentioned all three items of the attitude questionnaire. Prisoners had a good practice if they mentioned both items of the practice questionnaire. p values are from the χ^2 test. Data are n (%).

Table 5: **Knowledge, attitude, and practice related to tuberculosis among prisoners in intervention and control prisons in Ethiopia**

inmate peer educators successfully facilitated tuberculosis screening and supported treatment adherence for their fellow prison inmates.[4] Even though the study in India involved health professionals (and not peer educators) and the study in Zambia was only qualitative, both studies suggest that enhanced case finding with improved access to diagnostic services in prisons has value in improving tuberculosis case detection, consistent with our findings.

The findings of our study have important implications for clinical and public health policy, particularly in prisons of low-income countries where tuberculosis burden is high and the recommended tuberculosis diagnostic and treatment algorithms have generally not been implemented.[12,21] We show that tuberculosis case detection in resource-limited prisons could substantially improve if the prison inmates themselves were involved in the tuberculosis control programme. Very little financial support would be necessary to train the prisoners, with voluntary supervision done by prison health professionals. Previous evidence suggests that active case finding in addition to an entry and exit screening and frequent mass screening substantially improves case finding in prisons, and has been applied in prisons of high-income countries. However, shortage of trained health-care workers and resource scarcity limits the use of such a treatment algorithm in the prisons of low-income countries. In such resource-limited, high-risk settings, national tuberculosis control programmes should not only focus on adapting and introducing better screening and diagnostic tools (such as the Xpert MTB/RIF rapid assay), but should also give priority to potentially more feasible and sustainable public health interventions like those suggested in our study.

In a subgroup analysis of the smear status of prisoners with presumptive tuberculosis, the proportion of smear-negative cases detected was higher in the intervention prisons (61%) than in the control prisons (32%). This difference could be caused by the active screening being done not only for patients with prominent tuberculosis symptoms but also for those with mild symptoms (coughing for at least 2 or more weeks) who tend to be smear negative.[22,23] Patients with mild symptoms might have not been given priority for referral in control prisons since priority is given to those with severe symptoms who tend to be smear positive.[22] However, our reliance on routinely available diagnostic tools (smear microscopy and chest X-ray) without access to culture results (the gold standard diagnostic),[24] and the variability in performance of clinicians across hospitals could have also affected our results .

The ultimate goal of public health interventions that improve tuberculosis case finding should be to reduce tuberculosis burden through early detection and disruption of the chain of transmission.[25] With the continuous campaigns and active case finding organised by peer educators, and the subsequent preventive actions that were taken by inmates (for example, opening windows to disperse cough droplets) we anticipated that the majority of undiagnosed tuberculosis cases in the intervention prisons would be detected at the start of the one-year study period, unless new cases were constantly being introduced by new prisoners. However, in the trend analysis (figure 3) the number of tuberculosis cases detected remained high throughout the intervention period and might suggest a sustained transmission of the disease, caused by a relatively short intervention period. The effect of improved case finding on tuberculosis burden is likely to be seen only after several years of delay,[26] hence a trial could be considered over a period long enough to measure such an effect. A study[27] from a Bangladeshi prison, for example, showed an incredible drop in reported tuberculosis cases over five years after implementation of intensified case finding interventions. By contrast, infection prevention measures would have a minimal effect in prisons of poor countries with overcrowded and poorly ventilated prison cells, and segregation of symptomatic prison inmates is not practical because of the lack of space.[28]

Further analyses showed that prisons in Tigray had a better performance in finding cases than prisons in the Amhara region. This variation could partly be attributed to differences in the capacity and cooperation level of referral sites (hospitals). The hospitals in Tigray received

and investigated all referred prison inmates with presumptive tuberculosis, but one of the hospitals in the Amhara region raised concerns about resource availability and limited the number of presumptive tuberculosis cases to be investigated, giving priority to those inmates with prominent symptoms. This could have in turn, affected the performance of peer educators.

The odds of case finding increased with increasing baseline case notification rate. This relation is expected, as prisons with high prevalence of tuberculosis at baseline would tend to have a high burden of undiagnosed tuberculosis. Prisons with a high burden could be the ones that would benefit most from public health interventions such as those presented in our study. Furthermore, the proportion of prison inmates with a good knowledge and good practice was significantly higher in the intervention prisons. Previously, an intervention study[29] that involved health professionals showed improvements in the general awareness and practices surrounding tuberculosis in the general population in Ethiopia. Our study would have particular implications for addressing tuberculosis KAP gaps in prisons of resource-poor countries which have a shortage of health professionals.

One of the drawbacks of cluster-randomised trials is that baseline characteristics tend to distribute in an unbalanced manner among the groups if the clusters are few.[30] In our study, the randomisation was done after matching prisons into pairs, which avoids such an unbalanced distribution to a certain extent. Additionally, as the mean cluster size was high and the intervention effect large, the study had an acceptable level of statistical power. A possible limitation of this intervention was that we did not consider the dynamic nature of the prison population for estimation of the final outcomes. We considered the number of prison inmates at baseline of the study as a denominator for the estimation of the outcomes. However, data collected on the number of prison inmates at the study prisons each month during the intervention period showed that the average number of prison inmates did not vary significantly, suggesting that our estimation was still reliable. Another limitation could be a possible recall bias for some questions asked during routine screening, such as time of symptom development. We used a carefully constructed questionnaire with specific details and the participants were given enough time to think calmly and thoroughly before answering the questions to minimise such bias. Additionally, for long-term implementation of peer interventions in prisons the peer retention issue could be a challenge because of the subsequent release or transfer of the trained peers, so frequent recruitment and training might be needed.

The intervention model used in our study could be scaled up in other Ethiopian prisons and could possibly be adapted to other prisons in resource-limited countries with a high tuberculosis burden. In our study prisons, the prison inmates were socialised (staying in friendly groups and moving freely in the compound) and the prison health professionals and guards supported all activities related to the intervention. Prisons in other countries or regions might not have these same conditions, so they should be taken into account when considering implementation in other settings. With the scarcity of prison health professionals, high burden of undiagnosed tuberculosis, and the potentially similar conditions as in Ethiopian prisons,[28] we believe that our intervention model would be applicable to fight tuberculosis in prisons of other countries in sub-Saharan Africa. Our intervention model could also be applied to other health issues in prison populations. Evidence from systematic reviews of published studies in prisons[17,18] suggest that peer education interventions were acceptable to prison inmates and effective in reducing risky sexual behaviour, substantially reducing the risk of HIV transmission.

In conclusion, involving trained inmate peer educators in the tuberculosis control programme in Ethiopian prisons, significantly improved the tuberculosis case detection rate. Thus, this intervention model has a high potential for widespread implementation across Ethiopian prisons, and could be considered for adaptation by prisons in other resource-limited settings with a high burden of tuberculosis.

Contributors

KA, MS, and G-JD conceived the idea and designed the study. KA supervised the study and secured the data collection. KA, MS, and BW analysed data. KA, MS, BW, and G-JD contributed to the data interpretation and writing of the report.

Declaration of interests

We declare no competing interests.

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