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ORIGINAL ARTICLE

Cost-effectiveness analysis of an alternative tuberculosis management strategy for permanent farm dwellers in South Africa amidst health service contraction

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Abstract

Aim: To establish the cost-effectiveness of lay health workers (LHWs) in conjunction with the current, local tuberculosis (TB) control programme, amidst health service contraction. *Method:* A cost-effectiveness analysis, comparing direct time costs of the current TB management strategy among permanent farm dwellers, with an intervention, whereby LHWs are involved in TB control activities on farms. Measure of effectiveness was case finding and cure rates of adult new smear-positive (NSP) TB cases, alongside a randomized control trial (RCT): *Results:* The observed cost reduction to the Boland Health District was 74% per case detected and cured on the intervention farms relative to the control farms. Intervention farms reached 83% successful treatment completion rate, control farms 65%. Although the successful treatment adherence was significantly different (18% letter). The improved case detection and cure rates were not statistically significant (chi-squared test). Direct LHW costs are borne by farmers. Farmers were motivated to bear costs by reduced job absenteeism and other positive side-effects. Even without outcome improvements costs per case cured were 59% lower on the intervention farms. *Conclusion:* TB control has suffered from budget reductions in South Africa. It is critically important to develop cost-effective strategies to reduce the TB burden. Costs to public budgets can be substantially reduced while maintaining or improving case detection and treatment outcomes, by using farm-based LHWs.

Key Words: *Agriculture, cost-effectiveness analysis, lay health workers, farms, farmers, farm dwellers, farm workers, tuberculosis*

Background

Squire and Tang noted in a recent Lancet article that wider implementation of directly observed therapy, short-course (DOTS) strategy comes with careful and critical appraisal of what is needed to make DOTS work, especially where people, health infrastructures, and human resources are poor [1]. South Africa, like many sub-Saharan countries, witnessed a dramatic upsurge of TB cases over the past decade that is expected to continue, largely attributable to co-infection with the human immune-deficiency virus (HIV) [2]. South Africa has made considerable progress implementing the DOTS strategy since 1996, yet there is little sign that the epidemic is abating: during 1995–2001 pulmonary TB cases more than doubled, and the reported NSP rate was 188/100,000 in 2001 [3].

The 18% treatment interruption rate is the main reason for the South African National Tuberculosis Control Programme's poor performance [4]. Short-course anti-TB therapy utilizing a combination of drugs, recommended by the International Union Against Tuberculosis and Lung Disease and World Health Organization, is the standardized

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protocol of treatment in South Africa. Drugs are issued free to patients with TB, and conscientious adherence to treatment protocols has the potential to cure more than 95% of patients [5–8].

Direct observed treatment (DOT) is a component of DOTS, and is the recommended standard of care for enhancing anti-TB treatment adherence [9]. DOT incorporates the delegation to a second person (staff member or volunteer) the responsibility of ensuring that patients take each dose of anti-TB medication. South Africa has implemented DOT widely in urban areas at community level. Recent research studies in Africa indicated that community-based DOT could substantially reduce costs to health service providers and patients [10–13]. Most of the studies were, however, done in urban or semi-urban settings.

Some 22% of South Africa's farm workers are employed in the Western Cape. These farm dwellers are generally poor, have an exceptionally high incidence of TB, have low levels of education, and are chronically malnourished, despite spending a large proportion of their income on food, with a lifestyle socially and economically dependent on farmers [14]. TB, declared a provincial emergency during 1997, is the most common communicable disease in the Western Cape [9]. Although this province has 11% of the country's population, it carried the third greatest burden of TB disease, notifying 19% of the total national notifications, and in 2001 reporting an NSP incidence rate of 359/100,000 [3,7].

HIV prevalence reached 8.3% in 2001 in pregnant women attending formal health antenatal facilities in the study district [15]. The study district reported in 2001 an NSP TB incidence rate of 519/100,000 population (391 cases); a successfully completed treatment rate of 74%, and a treatment interruption rate of 17% for all TB cases [16]. DOTS was introduced here during 1997. Implementing DOT on farms is challenging and resource intensive.

Up to 1997 farms in the study district were visited fortnightly by nurse-staffed mobile clinics. Due to health budget cuts, health authorities centralized their healthcare delivery. Mobile clinic visits fell from 11,000 visits at 552 points in 1997 to 4,000 visits at 173 visiting points in 2000 – a 64% drop [16]. Farm dwellers now have to walk up to 5 km or be transported by farmers to attend either a mobile clinic on a centrally situated farm or a fixed clinic facility. Clinic services operate during office hours.

An LHW intervention was implemented on farms in the Boland health study district situated in the Western Cape Province of SA during the last decade [17,18]. Introducing trained LHWs on farms improved TB treatment adherence among adult patients [17]. A subsequent RCT found that for adult NSP TB cases the cure rate was 10% higher on farms with LHWs compared with farms without, while case detection was 42% higher on farms with LHWs (Table I) [18].

The observed outcome improvements are not statistically significant (chi-squared test) for case detection and cure rates. However, the successful treatment completion rate was 18% higher in the intervention group compared to the control group ($p=0.042$).

Table I. Adult NSP tuberculosis cases: Baseline and post-intervention comparisons – data on patient demographics and treatment outcomes.

	Baseline			Post-intervention		
Variable	Intervention No. (%)	Control No. (%)	Total No. (%)	Intervention No. (%)	Control No. (%)	Total No. (%)
Age groups (years)						
15–24	5 (15)	11 (26)	16 (21)	8 (17)	7 (17)	15 (17)
25–34	15 (46)	15 (36)	30 (40)	15 (32)	13 (31)	28 (31)
35+	13 (39)	16 (38)	29 (39)	24 (51)	22 (52)	46 (52)
Sex						
Male	18 (55)	19 (45)	37 (49)	28 (60)	27 (64)	55 (62)
Female	15 (45)	23 (55)	38 (51)	19 (40)	15 (36)	34 (38)
Total	33 (44)	42 (56)	75 (100)	47 (53)	42 (47)	89 (100)
Treatment outcomes						
Cure	22 (67)	28 (67)	50 (67)	31 (66)	25 (60)	56 (63)
Completed	4 (12)	5 (12)	9 (12)	8 (17)	2 (5)	10 (11)
Interrupted	5 (15)	5 (12)	10 (13)	2 (4)	11 (26)	13 (15)
Failed	0 (0)	3 (7)	3 (4)	4 (9)	2 (5)	6 (7)
Transferred out	2 (6)	1 (2)	3 (4)	1 (2)	0 (0)	1 (1)
Died	0	0	0	1 (2)	2 (5)	3 (3)

The Cape Winelands District Municipality is the local public healthcare provider for farm dwellers living on the farms in the Boland health district. The purpose of the intervention was to improve primary healthcare delivery, focusing on TB control, to those living and working on these farms. Local policy-makers have requested a cost-effectiveness analysis of this intervention before expanding within their district.

This paper describes a cost-effectiveness analysis, comparing alternative TB control programmes on the farms (see Table II) that implemented the LHW intervention.

Ethical approval was granted by the Interim Research Ethics Committee of the faculty of Applied Sciences of the Cape Technikon, Cape Town, South Africa and the Karolinska Institute, Stockholm, Sweden.

Aims

The study aimed to compare the cost-effectiveness of the two strategies for tuberculosis control among permanent farm dwellers by: (i) determining direct nursing time cost from when a person suspected of having NSP TB visits the clinic, until completing six months' treatment; (ii) determining direct time cost to farmers of having an LHW involved with TB screening, clinic referral of an NSP TB case, and supervising six months' treatment, and (iii) applying the time cost to the measures of effectiveness based on the findings of an RCT [18].

Material and methods

Study setting

Farms are large labour-intensive agricultural ''business units'' focusing on either fruit or wine products for export [14]. Each farmer employed 2–200 (median=18) permanent employees who live on these farms with their families. No public transport infrastructure is available to farms.

Voluntary participation in the RCT [18] was received from 211/409 registered farms in the study district. Each farm formed a cluster, the unit of randomization. The intervention group included 106/211 farms and the control group 105/211 farms. Altogether 78/106 (74%) of the intervention farms implemented the intervention, training 84 LHWs, with larger farms having more than one LHW. In total 4,438/8,887 (50%) people lived on farms in the intervention group, and 4,449/8,887 (50%) people lived on farms in the control group at baseline during 1999/2000. It is not easy for these people to relocate because of their limited education and level of competences. It is assumed that the population size remained constant during the study period.

Definitions

A LHW is ''any health worker carrying out functions related to health care delivery, trained in some way in the context of the intervention, and having no formal professional or certified tertiary education'' [19].

Cost-effectiveness analysis deals with alternatives that have a common and single outcome of interest, but have different degrees of success in achieving that outcome. [20].

Successful treatment completion refers to the sum of patients who are cured and those who have completed treatment [5].

NSP TB refers to patients who had never taken TB treatment, or had taken it for less than a month, and were diagnosed with active pulmonary TB [5].

The LHW intervention

All adult farm dwellers were involved in the process of selecting a suitable peer, already employed on the farm, to be trained and to function as a LHW on their farm. The intervention team consisted of an experienced clinic nurse as project manager, and two LHW trainers. This team conducted most (80%) of the training and was employed by the local health authority.

LHW training focused on TB, within the ambit of primary healthcare, using a community development framework, and applied adult basic training and education principles [20,21].

Farmers provided LHW transport to be trained, payment of LHWs whilst being trained and absent from their work on the farm; and paid the first aid training module, as it has become a legal requirement.

Alternative strategies

Two TB control strategies were compared, i.e. the current approach used in the study district (strategy 1), compared with strategy 2, using trained LHWs on the farms in conjunction with strategy 1. This study will provide insight into the impact of introducing farm community-based DOT in SA.

Table II. Summary of components of alternative tuberculosis management strategies.

Strategy	Case finding	Pre-diagnosis	Laboratory results to suspect	Treatment	No. of visits	Supervision	Programme management
Strategy 1 (current)	– Passive case finding as part of DOTS strategy, i.e. Self-referral when unwell	– Individual presents self on being sick	– Microscopy results available at clinic in 48 h	– Standard WHO treatment – see note[a] below	– Five days per week for both initial and continuation treatment phases	Attending clinic nurse at clinic if clinic-based DOT, otherwise clinic nurse working on mobile during monthly visits on that farm	Cape Winelands District Municipality
		– If attending clinic nurse suspects person to have TB, two sputum specimens are taken 90 minutes apart	– TB suspect requested to return after one week for results	– Clinic nurse informs patient of preferred option: clinic-based DOT	– Six– months period – 120 doses/visits to clinic for DOT or what the arrangement is with clinic nurse		
		– Sputum sent for laboratory microscopy (WHO procedures followed)	– Clinic nurse informs patient of sputum laboratory result	– If patient lives too far to attend daily DOT he/she is issued with 1–4 weeks' drug supplies, depending on distance from clinic			
			– If smear-positive, treatment commences and patient is requested to refer all direct contacts to clinic for TB screening – If smear-positive patient does not return for result (10%) clinic nurse recalls patient – If smear-negative antibiotics given; with request to return if symptoms persist				

Table II. (*Continued.*)

Strategy	Case finding	Pre-diagnosis	Laboratory results to suspect	Treatment	No. of visits	Supervision	Programme management
Strategy 2 (current in conjunction with LHW)	– Active monthly TB sign and symptom screening during out of harvest season	– LHW refers farm dweller with two or more TB-specific signs and symptoms with note to clinic	– LHW telephones clinic nurse after 48 h to get sputum results	– Same as for strategy 1	– As for strategy 1 except DOT is provided on farm in facility supplied by farmer or in home/place as agreed between patient and LHW	– LHW resident on the farm	Project team employed by the Cape Winelands District Municipality manages intervention together with community role players
	– During harvest season screening is done on individual request or LHW notices clinical changes, i.e. weight loss/cough >3 weeks	– LHW prepares referral of possible sputum specimen, explaining procedure	– LHW meets patient and give sputum result	– Clinic nurse discusses LHW DOT as preference with patient		– Clinic nurse working on mobile unit meets LHW and patient monthly during farm visits	
		– LHW obtains verbal consent to phone RN for sputum results if taken	– If smear-positive, immediately to clinic together with direct contacts for TB screening and patient commences treatment	– Patient selects DOT option		– LHW has telephone details of clinic nurse working on mobile clinic so that he/she can be contacted if needed	
		– Individual presents at clinic with LHW note, then as for strategy 1	– In most cases patient asks LHW to accompany him/her to clinic	– Medication replenishment via clinic nurse tasked to supervise treatment: either clinic nurse on mobile or in clinic			
		– Clinic nurse confirms LHW may be informed of sputum result	– If smear-negative, antibiotics given under LHW DOT – LHW refer back should symptoms persist				

[a]Treatment regimens: New patients receive weight-adjusted rifafour-E (rifampicin, isoniazid, pyrazinamide and ethambutol) five times per week during the intensive phase of 8 weeks. If they remain smear-negative at 8 weeks, they receive rifinah (rifampicin and isoniazid) five times a week for the following 16 weeks. If the patient remains smear-positive at 8 weeks, the intensive phase is continued to 12 weeks.

Essential components of each strategy are outlined in Table II. Our analyses refer only to adult (15 years and older) NSP TB cases. Time costs calculations include all staff activities included in both strategies. Cost of child, re-treatment, and multi-drug resistant (MDR) cases of TB have been excluded from this exercise.

Guidelines provided by the Department of Health do not indicate exact programme structures at district implementation level [8].

Data sources

The findings in terms of NSP TB treatment outcomes of the RCT [18] depicted in Table I were used as the effectiveness data source.

A clinic nurse working in a fixed clinic in the study area provided the first round of information. Every clinic activity is performed from when an adult TB suspect visits the clinic: performing TB diagnostic investigations; informing the patient of laboratory results; and supervising DOT for six months. Time per activity was estimated in minutes (personal communication, Mrs D van der Merwe, 5 April 2004). Flow diagrams were developed representing this information, which was verified by the six clinic nurses working in the study district. Taking two sputum specimens during the treatment period was excluded, as there is no difference between the alternatives studied.

An LHW with 11 years' experience provided the first round of information. Every activity performed on the farm in referring an adult TB suspect to the clinic, informing the patient of the laboratory results, and DOT supervision monitoring for six months was recorded. Time per activity was estimated in minutes (personal communication, Mrs M Muller, 5 April 2004). Flow diagrams were developed representing this information, which was verified during three separate discussion groups, held with 22 LHWs.

Time cost estimates for clinic nurses and enrolled nurses (non-professional nurses) were based on average salaries provided by the Cape Winelands District Municipality. Time cost estimates for LHWs were based on the mean wage using information provided by LHWs attending data verification groups.

A diagrammatic representation of the case detection and case holding within the alternative TB control strategies of permanent farm dwellers is given in Figure 1. Measure of effectiveness between the alternatives was based on adult NSP TB case finding, case holding, and cure rates. Information in decision trees flows from left to right, beginning with the initial decision indicated in the box defining the patient category. The squared node reflects actions taken, whereas the circular nodes reflect the chance effect of the particular action taken [20].

Estimation of costs

Costs were estimated simply, using a narrow range of direct costs based on the average clinic nurse and enrolled nurse packages, and the LHWs' mean salary. Relative time spent by the clinic nurse, enrolled nurse, or LHW on each activity pertaining to NSP TB patients was calculated in broad terms, i.e. allocating salary costs in proportion to the time spent on each activity. Costs were calculated for strategy 1 and strategy 2 as alternatives to control TB on farms (see Table IV and Figure 1). Time period costs were collected for a six-month period, whereas the effectiveness data [17] were collected for one year (see Table I).

Some costs were not examined, i.e. transport, overhead, and facility costs, as these operational and overhead costs were logistically impossible to

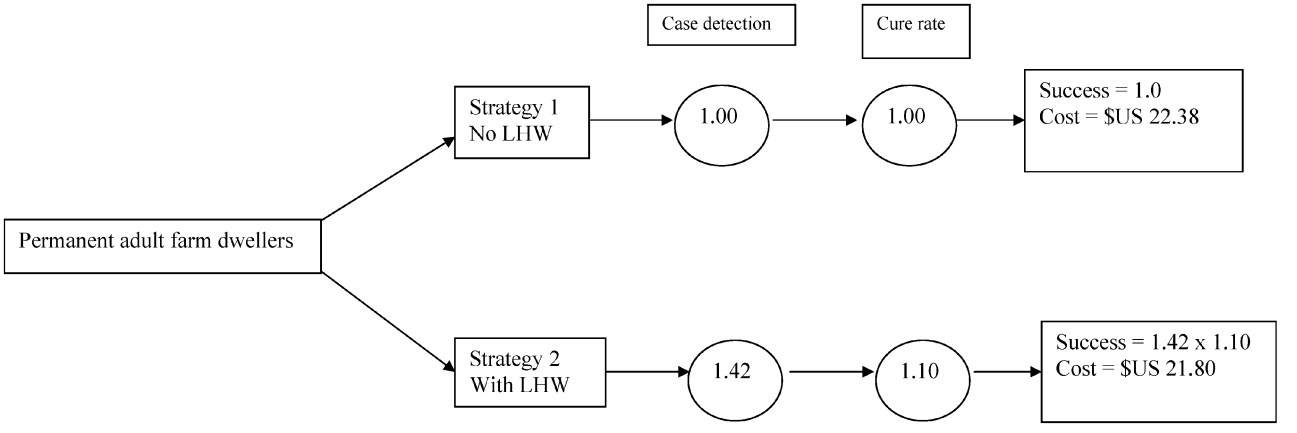

Figure 1. Diagrammatic representation: NSP TB case detection and cure rate within the two alternative strategies.

determine for the LHWs, who used farm infrastructure and facilities. Furthermore, the purpose was to provide empirical evidence for decisions on how better to use public money for health improvements and survival. The cost perspective that we have applied was that of the Boland Health District.

Costing

Costs are presented in US dollars, applying the SA currency exchange rate on 30 June 2004, i.e. US$1=R (SA Rand) 6.23 [22]. The time cost for each activity was calculated in SA currency and converted to US dollars (see Table IV).

Table III. Time cost per minute (expressed in US$) of DOT providers.

Directly Observed Treatment (DOT) provider	Cost per week	Cost per minute worked (2 400 minutes per week)
Clinic nurse	277.85	0.12
Enrolled nurse	185.23	0.08
Lay health worker	32	0.01

Results

Time cost calculations are presented in Table III. The cost per minute for clinic nurses was calculated US$ 0.12, for enrolled nurses US$ 0.08, and for LHWs US$ 0.01. The local health authority funded the nurses, whereas farmers paid the LHWS.

The marginal time cost of the LHW to the farmer for screening, case finding, referral, and treatment of an NSP TB case in an intervention farm, amounted to US$ 12.68 during low season and for self-referral during high season and to US$ 12.91 when not self-referred during high season (Table IV).

The marginal time cost of diagnosis and clinical consultation in the formal health sector for the cases referred by the LHW amounted to US$ 9.12 per case (see Table IV), yielding a total marginal cost (private and public) per case of US$ 21.80 for the cases screened in low season or self-referred in high season and US$ 22.03 for cases not self-referred during high season.

The marginal time cost of an NSP TB case in the non-intervention farms was US$ 19.80 when no recall was required and US$ 25.80 when recall was necessary (see Table IV). Recall was required in

Table IV. Time cost per NSP tuberculosis case: Incumbent responsible for different activities and funded by whom.

Incumbent/cost per minute	Activity	Minutes	Cost: US$	Funded by
Enrolled nurse Cost: US$ 0.08	1. Take and record vital signs	15	1.2	Formal health sector
Clinic nurse Cost: US$ 0.12	2. Physical assessment and sputum collection	15	1.80	
	3. Inform patient of sputum result and DOT	20	2.40	
	4. Inform LHW of sputum laboratory result	1	0.12	
	5. Daily clinic-based DOT (1 min × 120 doses	120	14.40	
	6. Patient recall	50	6.00	
	7. Mobile: monthly LHW support during DOT period (5 min × 6 times)	30	3.60	
	8. Mobile: monthly patient support during DOT – if no LHW (see 7)	30	3.60	
Lay health worker Cost: US$ 0.01	9. Tuberculosis screening during high season: LHW approaches person	30	0.30	Farmer
	10. Individual requests tuberculosis screening during high season	7	0.07	
	11. Tuberculosis screening during low season	7	0.07	
	12. LHW informed by RN of sputum laboratory result	1	0.01	
	13. Informs new tuberculosis patient of sputum laboratory result	10	0.10	
	14. Meets with clinic nurse and patient: discuss DOT/treatment on farm	20	0.20	
	15. Oversee DOT on farm to patient (10 min × 120 doses)	1200	12.00	
	16. Meets patient and clinic nurse: monthly farm visits (5 × 6 times)	30	0.30	

Cost to the farmer (only farms where intervention took place): (US$ 12.61 for case holding only – activity numbers 12–16). During low season or on individual request: activity numbers: 10/11, 12, 13, 14, 15 and 16=US$ 12.68. During high season (LHW notices clinical changes): activity numbers 9, 12, 13, 14, 15, and 16=US$ 12.91. Cost to FHS: Intervention took place: With trained LHW on farm: Activity numbers 1, 2, 3, 4, and 7=US$ 9.12. No intervention took place (control farms). Without trained LHW on farm and no patient recall and clinic-based DOT: Activity numbers: 1, 2, 3, and 5=US$ 19.80. Without LHW on farm and patient recall required plus clinic–based DOT: Activity numbers: 1, 2, 3, 5, and 6=US$ 25.80. Without LHW on farm, patient lives too far to attend for clinic-based DOT and no recall: Activity numbers: 1, 2, 3, and 8=US$ 9.12 *Not promoted.* Without LHW on farm, patient lives too far to attend for clinic-based DOT and recall was required: Activity numbers: 1, 2, 3, 6 and 8=US$ 15.00 *Not promoted.*

approximately 10% of the cases in the non-intervention farms, while it did not occur in the intervention farms. This yields a mean marginal time cost of US$ 22.38 (19.80+(10% × 25.80)) per NSP TB case in the non-intervention farms.

The intervention farms had a 42% ((47/33)/(42/42) (Calculating using number of cases)) better NSP TB case finding and 10% better cure rate ((66%/67%)/(60%/67%)) relative to the control farms (see Table I). Assuming that the observed average improvements in case detection rate, case holding, and cure rate will be sustained in an expansion of the intervention and ignoring the impact on multi-drug resistance and other side effects of the intervention, the expected cost-effectiveness of the intervention can be calculated as (US$ 9.12/(1.10 × 1.42))/US$ 22.38)=0.26. Inversely, this implies that public money spent in the context of an LHW project will have an impact almost four times that of the conventional strategy. In the intervention farms case detection was active and no recalls have been required. Case holding was 56% better on the intervention farms (1.1 × 1.42=1.562=56%). Assuming this performance is maintained, the expected total time cost reduction for the formal health sector reduced by the added time for screening by the LHW would be 74%.

Sensitivity

The improved case holding and cure rates will have secondary preventive effects. If the observed average improvements in case detection and cure rate are sustained during an expansion, it will lead to a reduction of MDR TB, with potential huge cost reductions. Each case of multi drug-resistant tuberculosis costs up to US$ 2,585 in drug cost alone [24].

Even if the observed outcome improvements are discounted, the intervention still resulted in a cost reduction of 59% per case cured relative to the control farms. During the intervention other positive side effects have been obvious: improved social conditions, reduced alcoholism, less violence, and an increase in out-of-work activities, e.g. sports and gardening. Obviously, the external effects, including reduction of job absenteeism, are seen by the farmers as sufficiently positive to convince them that paying for the LHW is worthwhile.

Discussion

Our study provides an important estimation of cost-effectiveness data on alternative TB management strategies for permanent farm dwellers, data that were not previously available (see Table IV and Figure 1). This simplified, context-specific community participative intervention was cost-effective in TB control among permanent adult farm dwellers.

The intervention farms with LHWs reached 83% successful treatment completion rate at 26% of the public cost of the control farms (current TB control programme), which only reached a 64% rate among NSP TB cases (see Tables I and IV and Figure 1).

SA is in the midst of a maturing HIV/AIDS epidemic. As the HIV epidemic unfolds in the Western Cape, a 10% increase in recurrent and more drug-resistant TB cases is expected [24]. Case-finding activities should only start once a low treatment interruption rate is achieved to prevent secondary TB cases from developing [28]. LHWs reached a respectable 4% treatment interruption rate for NSP TB farm dwellers, whereas this rate on farms without LHWs was 26% (see Table I).

It is estimated that between 10% and 15% of secondary TB cases occur per primary case left untreated: five new secondary infections every six months. In this study we found improvements in both case detection and cure rates that will have a multiplying effect in addition to the cost savings we have observed.

Approximately 69% of the total treatment cost per TB patient comprises staff time costs [7]. Introducing LHWs has the potential to reduce this staff time cost by 74%. The clinic nurse spends about 50 min on each patient recall, whereas no patient recalls were required where LHWs functioned.

LHWs were able to assimilate and transfer their training in to their cultural-social context, and in so doing satisfied formal health's need for disease control. LHWs were able to make DOT physically, socially, and economically accessible to TB patients [27].

Export farmers are required to comply with regulations governing worker health and social well-being. LHWs assist farmers in their efforts to improve the health and welfare of the workers and as a side effect contribute to more effective and profitable production.

Can our findings be applied to the commercial agricultural sector of SA? The LHW model has been rigorously evaluated using an RCT [18]. The perceptions of those involved were evaluated using qualitative research methods, providing insight into the process required to successfully implement this strategy in a sustainable way [28,29]. The LHW strategy has proved affordable within current cost constraints and acceptable within the current infrastructure. Thus it offers hope as a strategy to cope with the expected increased TB caseload as the HIV/

AIDS pandemic unfolds. Cost-effectiveness analyses form only part of the decision-making process. Policy-makers may consider incorporating aspects of these findings, as actual implementation would need to be guided by local circumstances, mindful that inefficient allocation of scarce resources exacts a much higher penalty in terms of forgone health benefits in rural areas with high TB prevalence.

Our study points way to a more cost-effective TB strategy to improve health and survival in resource-poor settings.

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