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Investigating the Role of Vitamin D Supplementation in Reducing Tuberculosis Recurrence in High-Risk Population of Adults and Children.

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Abstract

Background: Tuberculosis (TB) recurrence arising from either endogenous relapse or exogenous reinfection remains a major obstacle to TB elimination, particularly in high-burden countries such as India. Vitamin D plays a well-established immunomodulatory role in the host defence against Mycobacterium tuberculosis, and vitamin D deficiency has been repeatedly linked with active TB disease and poorer treatment outcomes. ***Objective:*** To evaluate whether adjunct vitamin D supplementation during and after anti-tubercular therapy (ATT) reduces the rate of bacteriologically confirmed TB recurrence at 24 months in a high-risk cohort of adults and children. ***Materials and Methods:*** A prospective, open-label, parallel-group cohort study was conducted at a tertiary-care teaching hospital over a 30-month period. A total of 420 participants (adults, n = 300; children aged 6-14 years, n = 120) who had completed standard first-line ATT and were classified as high-risk (baseline serum 25-hydroxyvitamin D [25(OH)D] < 20 ng/mL, malnutrition, diabetes mellitus, or close household contact with a multidrug-resistant TB case) were allocated to receive either oral cholecalciferol supplementation (60,000 IU weekly for 8 weeks followed by 60,000 IU monthly for 16 months) plus standard post-treatment follow-up, or standard follow-up alone. Serum 25(OH)D was measured at baseline, 3, 12, and 24 months. The primary outcome was microbiologically confirmed TB recurrence within 24 months. ***Results:*** Baseline vitamin D deficiency (<20 ng/mL) was present in 71.4% of participants. At 24 months, TB recurrence occurred in 6.2% (13/210) of the supplementation group compared with 14.3% (30/210) of the standard-care group (relative risk 0.43, 95% CI 0.23-0.80, p = 0.004). The benefit was more pronounced in children (recurrence 5.0% vs 16.7%, p = 0.01) than in adults (6.7% vs 13.3%, p = 0.03). Participants who achieved serum 25(OH)D ≥ 30 ng/mL by 3 months had the lowest recurrence rate (4.1%) compared with those who remained deficient (18.9%). ***Conclusion:*** Adjunct vitamin D supplementation was associated with a clinically and statistically significant reduction in TB recurrence among high-risk adults and children, particularly when biochemical sufficiency was achieved early. These findings support incorporation of vitamin D status screening and targeted supplementation into post-ATT follow-up protocols in high-burden, deficiency-prone settings such as India.

Keywords: Tuberculosis recurrence; Vitamin D; Cholecalciferol; 25-hydroxyvitamin D; Relapse; Reinfection; High-risk population; Children; India.

INTRODUCTION

Tuberculosis (TB) remains one of the leading infectious causes of death worldwide, and India continues to bear the largest share of the global burden [1], accounting for a substantial proportion of incident cases and mortality despite four decades of a national control programme. While the primary focus of TB control has historically been on case detection and completion of anti-tubercular therapy (ATT), a growing body of evidence indicates that a clinically important fraction of successfully treated patients subsequently develop recurrent disease, either through endogenous relapse of an incompletely sterilised focus or through exogenous reinfection with a new strain [2,3]. Recurrence not only inflicts additional morbidity and cost on the patient and health system but also contributes disproportionately to onward transmission and to the emergence of drug resistance.

In India, post-treatment recurrence rates of 5-10% within two years have been documented under programmatic conditions, with higher rates reported among patients with residual cavitary disease, malnutrition, diabetes mellitus, and household exposure to infectious contacts [4,5]. The National Strategic Plan for TB Elimination has explicitly identified reduction of recurrence and relapse as a priority area, given India's goal of eliminating TB well ahead of the global 2030 target.

Identifying low-cost, scalable adjunct interventions that can be layered onto the existing programmatic framework is therefore of considerable public health relevance.

Vitamin D has long been recognised as more than a regulator of calcium-phosphate homeostasis; it is a key modulator of innate and adaptive immunity against Mycobacterium tuberculosis. Activation of the vitamin D receptor pathway in macrophages upregulates cathelicidin, an antimicrobial peptide that directly restricts intracellular mycobacterial growth [6], and vitamin D supplementation has been shown to enhance monocyte-mediated immunity to mycobacteria in human volunteers [7]. Vitamin D deficiency defined variably as serum 25-hydroxyvitamin D [25(OH)D] below 20 ng/mL is now recognised as a global public health problem [8], and its geographic and seasonal distribution overlaps closely with regions of high TB endemicity, prompting the hypothesis of a causal or at least a permissive relationship between hypovitaminosis D and TB susceptibility [9].

A widely cited systematic review and meta-analysis of observational studies concluded that individuals with active TB have significantly lower serum 25(OH)D concentrations than healthy controls [10], and subsequent large randomised trials have tested whether correcting this deficiency can prevent incident TB disease or improve outcomes on treatment. The landmark Mongolian trial of vitamin D supplementation in schoolchildren demonstrated a reduction in TB infection acquisition as measured by interferon-gamma release assay conversion [11], while a placebo-controlled trial from Guinea-Bissau showed accelerated sputum culture conversion with high-dose adjunct cholecalciferol in patients carrying a specific vitamin D receptor genotype [12]. A double-blind randomised controlled trial conducted in South India similarly reported improved radiological and clinical resolution with adjunct vitamin D during the intensive phase of treatment [13], lending further support to a biologically plausible and geographically relevant role for vitamin D in the Indian context.

Indian data specific to the paediatric population are particularly informative. A case-control study from North India found significantly lower serum 25(OH)D levels in children with culture-confirmed TB compared with age- and sex-matched healthy controls [14], and hospital-based studies among adult pulmonary TB patients in India have documented deficiency prevalences ranging from 60% to over 90%, considerably higher than would be expected in a tropical, sun-abundant country [15,16]. This paradoxically high prevalence of deficiency in India has been attributed to conventional clothing practices, indoor occupations, urban air pollution reducing effective ultraviolet-B penetration, skin pigmentation, and low dietary intake of vitamin D-fortified foods, and has been documented across the lifespan from schoolchildren to older adults [17,18].

Malnutrition and diabetes mellitus, both highly prevalent comorbidities in the Indian TB-affected population, independently impair cell-mediated immunity and are established risk factors for both primary TB and recurrence [19,20]. Because vitamin D deficiency, undernutrition, and diabetes frequently co-exist in the same patients, correction of vitamin D status has been proposed as a pragmatic, low-cost adjunct strategy that could plausibly reduce the residual bacillary burden at the time of treatment completion and thereby lower the risk of subsequent relapse, while also modulating susceptibility to reinfection on renewed exposure.

Despite this strong mechanistic and epidemiological rationale, very few studies particularly from India have specifically examined whether post-treatment vitamin D supplementation reduces long-term TB recurrence, as opposed to short-term markers of treatment response such as sputum conversion or radiological resolution. Moreover, most existing adjunct-vitamin-D trials have been conducted exclusively in adults, leaving a substantial evidence gap for children, who constitute a growing proportion of the notified TB burden in India and who may respond differently to supplementation because of their distinct immunological maturity and nutritional vulnerability.

Objectives of the present study: To determine the baseline prevalence of vitamin D deficiency among high-risk adults and children completing ATT at a tertiary-care teaching hospital and to examine the dose-response relationship between achieved serum 25(OH)D concentration and recurrence risk, separately in adult and paediatric subgroups.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective, open-label, parallel-group cohort study conducted in the Department of Pulmonary Medicine and the Department of Paediatrics of a tertiary-care teaching hospital in India, in collaboration with the local unit of the National Tuberculosis Elimination Programme (NTEP). The study was conducted over a 30-month period, comprising 6 months of enrolment and a minimum follow-up of 24 months for each participant.

Study Population

Adults (≥18 years) and children (6-14 years) who had successfully completed a standard first-line, six-month ATT regimen (2HRZE/4HR, administered under NTEP guidelines) for microbiologically confirmed drug-sensitive pulmonary TB were

screened for eligibility at the time of treatment completion. Participants were classified as "high-risk" for recurrence if they met at least one of the following pre-specified criteria: (a) baseline serum 25(OH)D concentration below 20 ng/mL; (b) body mass index/weight-for-age below the 5th percentile (malnutrition); (c) co-existing type 2 diabetes mellitus; or (d) household contact with a bacteriologically confirmed multidrug-resistant TB case within the preceding 12 months.

Inclusion and Exclusion Criteria

Inclusion criteria: Age 6 years and above; completion of standard first-line ATT with documented treatment success (cured or treatment completed); willingness to provide written informed consent/assent; residence within the catchment area permitting 24-month follow-up.

Exclusion criteria: Known hypercalcaemia, nephrolithiasis, or chronic kidney disease; pre-existing granulomatous disorders other than TB (e.g., sarcoidosis); HIV co-infection; pregnancy; known drug-resistant TB; current use of vitamin D or calcium supplements at doses exceeding the recommended dietary allowance; and inability to attend scheduled follow-up visits.

Sample Size

Assuming a baseline 24-month recurrence rate of 14% in the standard-care group (based on prior Indian programmatic data) and hypothesising a reduction to 6% with adjunct vitamin D supplementation, a sample size of 200 participants per group was calculated to provide 80% power at a two-sided alpha of 0.05, using a two-proportion z-test. Allowing for an anticipated 10% loss to follow-up, 210 participants were enrolled per group (total N = 420).

Allocation and Intervention

Participants were allocated to the intervention or standard-care group using a computer-generated randomisation sequence, stratified by age category (adult/child) and baseline vitamin D status (deficient/insufficient/sufficient), in a 1:1 ratio. Given the nature of the intervention, the study was open-label; however, laboratory personnel measuring serum 25(OH)D and the microbiologist assessing sputum/gastric aspirate culture results for the primary outcome were blinded to group allocation.

Participants in the intervention group received oral cholecalciferol 60,000 IU once weekly for 8 weeks (loading phase), followed by 60,000 IU once monthly for 16 months (maintenance phase), in addition to standard post-treatment follow-up under NTEP protocol. Children received a weight-adjusted equivalent dose (60,000 IU weekly for 6 weeks, then monthly). Participants in the standard-care group received routine post-treatment follow-up alone, consisting of clinical review and sputum smear microscopy at 6, 12, 18, and 24 months, without vitamin D supplementation unless clinically indicated for other reasons, in which case they were analysed as a protocol deviation.

Outcome Measures

Primary outcome: Bacteriologically confirmed pulmonary TB recurrence (positive sputum smear/culture or Xpert MTB/RIF, with clinical and/or radiological correlation) within 24 months of treatment completion.
Secondary outcomes: Change in serum 25(OH)D concentration from baseline to 3, 12, and 24 months; proportion achieving biochemical sufficiency (≥30 ng/mL); all-cause mortality; and adverse events attributable to supplementation (hypercalcaemia, nephrolithiasis, gastrointestinal intolerance).

Laboratory Methods

Serum 25(OH)D was measured using a chemiluminescent immunoassay (CLIA) at a centralised, quality-assured laboratory. Vitamin D status was categorised as deficient (<20 ng/mL), insufficient (20-29.9 ng/mL), or sufficient (≥30 ng/mL), consistent with commonly used thresholds in the Indian literature. Serum calcium, phosphate, and creatinine were monitored at each supplementation visit to screen for toxicity.

Statistical Analysis

Data were analysed on an intention-to-treat basis using SPSS version 26.0. Categorical variables were summarised as frequencies and percentages and compared using the chi-square or Fisher's exact test as appropriate. Continuous variables were expressed as mean ± standard deviation or median (interquartile range) and compared using Student's t-test or the Mann-Whitney U test. Cumulative incidence of recurrence was compared between groups using relative risk (RR) with 95% confidence intervals (CI), and time-to-recurrence was analysed using Kaplan-Meier survival curves with the log-rank test. Multivariable Cox proportional hazards regression was used to adjust for pre-specified confounders (age, baseline vitamin D status, nutritional status, diabetes status, and drug-resistant contact history). A two-sided p-value <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all adult participants and from parents/guardians of paediatric participants, with assent obtained from children aged 7 years and above. The study was conducted in accordance with the Declaration of Helsinki and Indian Council of Medical Research (ICMR) National Ethical Guidelines for Biomedical and Health Research Involving Human Participants.

RESULTS

A total of 452 patients completing ATT were screened for eligibility, of whom 420 met the high-risk criteria and were enrolled (210 per group). Twenty-two participants (10.5%) in the intervention group and 24 (11.4%) in the standard-care group were lost to follow-up or withdrew consent before 24 months; the remaining participants were included in the intention-to-treat analysis, with missing outcome data handled conservatively (loss to follow-up treated as non-recurrence for the primary analysis, with a sensitivity analysis performed treating losses as recurrences).

Baseline Characteristics

Baseline demographic, clinical, and biochemical characteristics were comparable between the two groups (Table 1), confirming adequacy of randomisation. The overall prevalence of baseline vitamin D deficiency (<20 ng/mL) in the study cohort was 71.4% (300/420), with a further 21.0% classified as insufficient and only 7.6% biochemically sufficient at enrolment.

Table 1. Baseline demographic and clinical characteristics of study participants

Characteristic	Vitamin D group (n=210)	Standard-care group (n=210)	p-value
Age, years (mean ± SD)	28.6 ± 14.2	29.1 ± 13.8	0.71
Children (6-14 y), n (%)	60 (28.6)	60 (28.6)	1.00
Male sex, n (%)	124 (59.0)	119 (56.7)	0.62
BMI <18.5 kg/m² (adults), n (%)	81 (54.0)	78 (52.0)	0.71
Type 2 diabetes mellitus, n (%)	58 (27.6)	55 (26.2)	0.75
MDR-TB household contact, n (%)	34 (16.2)	31 (14.8)	0.68
Baseline 25(OH)D, ng/mL (mean ± SD)	15.8 ± 6.1	16.3 ± 6.4	0.42
Cavitary disease on baseline CXR, n (%)	72 (34.3)	69 (32.9)	0.76
Smoking history (adults), n (%)	47 (31.3)	44 (29.3)	0.72

SD = standard deviation; BMI = body mass index; MDR-TB = multidrug-resistant tuberculosis; CXR = chest X-ray.

Change in Vitamin D Status Over Time

Serum 25(OH)D rose progressively in the supplementation group, with 78.1% achieving biochemical sufficiency (≥30 ng/mL) by 3 months, sustained through 24 months. In contrast, vitamin D status in the standard-care group showed minimal spontaneous improvement (Table 2, Figure 1 description below).

Table 2. Serum 25-hydroxyvitamin D concentration (ng/mL) over the follow-up period

Time point	Vitamin D group (mean ± SD)	Standard-care group (mean ± SD)	p-value
Baseline	15.8 ± 6.1	16.3 ± 6.4	0.42
3 months	34.2 ± 8.7	18.1 ± 6.9	<0.001
12 months	38.6 ± 9.1	19.4 ± 7.2	<0.001
24 months	36.9 ± 8.4	20.1 ± 7.8	<0.001

Primary Outcome: TB Recurrence at 24 Months

Overall, bacteriologically confirmed TB recurrence occurred in 43 of 420 participants (10.2%) during 24 months of follow-up. Recurrence was significantly less frequent in the vitamin D supplementation group than in the standard-care group (Table 3).

Table 3. Primary outcome — TB recurrence at 24 months, overall and by age group

Group	Recurrence, n/N (%)	Relative Risk (95% CI)	p-value
Overall — Vitamin D group	13/210 (6.2)	0.43 (0.23-0.80)	0.004
Overall — Standard-care group	30/210 (14.3)	Reference	—
Adults — Vitamin D group	10/150 (6.7)	0.50 (0.24-1.03)	0.03
Adults — Standard-care group	20/150 (13.3)	Reference	—
Children — Vitamin D group	3/60 (5.0)	0.30 (0.09-1.02)	0.01
Children — Standard-care group	10/60 (16.7)	Reference	—

CI = confidence interval. Relative risk <1 favours the vitamin D supplementation group.

Recurrence by Achieved Vitamin D Status

When participants were stratified by the serum 25(OH)D concentration achieved at 3 months (irrespective of original allocation), a clear dose-response gradient was observed, with the lowest recurrence rate among those who achieved biochemical sufficiency (Table 4).

Table 4. TB recurrence stratified by 25(OH)D concentration achieved at 3 months

Achieved 25(OH)D category	N	Recurrence, n (%)	p-value (trend)
Deficient (<20 ng/mL)	122	23 (18.9)	<0.001
Insufficient (20-29.9 ng/mL)	104	12 (11.5)	
Sufficient (≥30 ng/mL)	170	7 (4.1)	

Multivariable Analysis

On multivariable Cox regression adjusting for age category, baseline nutritional status, diabetes, and MDR-TB contact history, vitamin D supplementation remained independently associated with reduced recurrence risk (adjusted hazard ratio [aHR] 0.41, 95% CI 0.22-0.77, p = 0.006). Malnutrition (aHR 1.92, 95% CI 1.04-3.54, p = 0.04) and cavitary disease at baseline (aHR 1.88, 95% CI 1.01-3.51, p = 0.047) were independently associated with increased recurrence risk (Table 5).

Table 5. Multivariable Cox proportional hazards analysis for predictors of TB recurrence

Variable	Adjusted HR	95% CI	p-value
Vitamin D supplementation (vs standard care)	0.41	0.22-0.77	0.006
Baseline malnutrition	1.92	1.04-3.54	0.04
Diabetes mellitus	1.46	0.78-2.73	0.24
Cavitary disease at baseline	1.88	1.01-3.51	0.047
MDR-TB household contact	1.35	0.65-2.79	0.42
Paediatric age group (vs adult)	0.79	0.38-1.65	0.53

Safety and Tolerability

Adjunct vitamin D supplementation was well tolerated. Mild, asymptomatic hypercalcaemia (corrected serum calcium 10.3-10.8 mg/dL) was observed in 3.8% (8/210) of the supplementation group, resolving with a single dose omission and reduced maintenance dosing; no participant developed nephrolithiasis, symptomatic hypercalcaemia, or required discontinuation of therapy (Table 6).

Table 6. Adverse events during the supplementation and follow-up period

Adverse event	Vitamin D group n (%)	Standard-care group n (%)
Mild asymptomatic hypercalcaemia	8 (3.8)	0 (0.0)
Gastrointestinal intolerance	5 (2.4)	2 (1.0)
Nephrolithiasis	0 (0.0)	0 (0.0)
All-cause mortality	2 (1.0)	4 (1.9)

Kaplan-Meier survival analysis demonstrated visible separation of the recurrence-free survival curves between groups from approximately month 9 onward, with the divergence widening progressively through 24 months (log-rank p = 0.003), consistent with a cumulative protective effect of sustained vitamin D sufficiency rather than an early, transient benefit.

DISCUSSION

In this prospective cohort of high-risk adults and children completing first-line ATT in North India, adjunct vitamin D supplementation was associated with a 57% relative reduction in bacteriologically confirmed TB recurrence at 24 months, with the effect remaining significant after adjustment for known confounders. A clear biological gradient was observed: participants who achieved biochemical vitamin D sufficiency (≥30 ng/mL) had the lowest recurrence rate, while those who remained deficient despite the overall follow-up period fared no better than untreated controls. This dose-response relationship strengthens the inference of a genuine biological effect rather than a chance finding or confounding by indication.

The very high baseline prevalence of vitamin D deficiency observed in this cohort (71.4%) is consistent with earlier Indian reports describing deficiency prevalences of 60-90% among pulmonary TB patients despite India's abundant year-round sunshine [15,16]. This so-called "Indian paradox" of widespread hypovitaminosis D in a tropical country has been attributed

to cultural practices limiting sun exposure, atmospheric pollution, and low dietary intake of vitamin D-rich foods, and has been documented across all age groups, from schoolchildren in sub-Himalayan states [27] to community-dwelling older adults [18]. Our findings extend this literature by demonstrating that this deficiency is not merely a marker of disease severity but is mechanistically linked to a clinically important downstream outcome — recurrence after apparently successful treatment.

The magnitude of benefit observed here is broadly consistent with, and in the paediatric subgroup somewhat larger than, effects reported in prior adjunct-vitamin-D trials. The Guinea-Bissau trial reported accelerated sputum conversion with high-dose cholecalciferol, particularly among patients with a specific vitamin D receptor genotype [12], while the South Indian RCT of adjunct vitamin D during intensive-phase treatment reported improved clinico-radiological resolution [13]. An individual participant data meta-analysis of adjunct vitamin D trials found an overall modest effect on sputum culture conversion but noted substantial heterogeneity, with the strongest signal in vitamin-D-deficient subgroups [23] — a pattern mirrored in our own stratified analysis by achieved 25(OH)D concentration. Mechanistically, vitamin D has been shown to accelerate resolution of pulmonary inflammatory responses during treatment [22] and to enhance macrophage-mediated killing of intracellular mycobacteria through cathelicidin induction [6], both of which could plausibly reduce residual bacillary burden at treatment completion and thereby lower relapse risk, while a sustained sufficient vitamin D status may also confer ongoing protection against reinfection on renewed exposure, analogous to the infection-prevention signal seen in the Mongolian schoolchildren trial [11].

The particularly strong effect observed in children in our cohort (recurrence 5.0% vs 16.7%) is noteworthy and is broadly concordant with a meta-analysis suggesting a protective association between vitamin D sufficiency and TB risk in children [24], as well as with the case-control study from North India documenting markedly lower 25(OH)D concentrations among children with confirmed TB compared with matched healthy controls [14]. Children may derive greater benefit both because their immune systems are still maturing and are more responsive to immunomodulation, and because paediatric malnutrition — itself a strong independent risk factor for recurrence [19,29] — frequently coexists with vitamin D deficiency, so correcting the latter may partially offset the immunological deficit imposed by the former.

Independent predictors of recurrence identified in our multivariable model malnutrition and cavitary disease at baseline are well established in the Indian and international literature. Cavitary disease reflects a higher residual mycobacterial burden and slower sterilisation [17], while malnutrition impairs cell-mediated immunity through multiple pathways, including reduced lymphocyte proliferation and cytokine dysregulation [19,29]. A South Indian DOTS-cohort study similarly identified low body weight and cavitary disease as predictors of relapse [25], and a study of post-treatment sputum-positive patients from South India found that incomplete radiological resolution at treatment completion predicted poorer long-term outcomes [26]. Host genetic factors, including vitamin D receptor polymorphisms shown to influence cytokine responses in South Indian TB patients [10,21] and other susceptibility loci [28], may further explain the variable individual response to supplementation observed in our cohort, and represent an important avenue for future research aimed at identifying which patients are most likely to benefit.

From a programmatic perspective, these findings are directly relevant to India's National TB Elimination Programme. With India's TB Report documenting notification of a substantial paediatric case load annually and highlighting recurrence and relapse as a persistent challenge to elimination targets [30], a low-cost, orally administered, monthly-dosed intervention such as cholecalciferol is highly compatible with the operational constraints of a high-volume public health programme. Vitamin D supplementation is inexpensive, has an established safety profile at the doses used here, and does not require the cold-chain or injection infrastructure that limits some other adjunct interventions. Integrating baseline vitamin D screening or, where resource constraints preclude universal testing, empirical supplementation of all high-risk post-ATT patients into routine post-treatment follow-up protocols could represent a pragmatic addition to the existing NTEP framework.

Strengths and Limitations

This study has several strengths, including a prospective design with pre-specified high-risk criteria, biochemically confirmed vitamin D status at multiple time points, bacteriologically confirmed (rather than purely clinical) outcome ascertainment, and inclusion of both adult and paediatric populations, which remain under-represented in the existing literature. Nonetheless, several limitations merit consideration. First, the open-label design, necessitated by the practical difficulty of blinding an oral supplementation regimen against placebo in a programmatic setting, could have introduced ascertainment or performance bias, although outcome assessors were blinded to allocation.

Second, whole-genome sequencing to definitively distinguish relapse from exogenous reinfection was not performed; recurrence was therefore classified using clinical and bacteriological criteria alone. Third, the study was conducted at a single tertiary-care centre, which may limit generalisability to primary-care or rural programmatic settings with different

deficiency prevalences and dietary patterns. Finally, the sample size, while adequately powered for the primary outcome, limited the precision of subgroup analyses, particularly in children, and the reported effect sizes should be interpreted with appropriate caution pending confirmation in larger, ideally placebo-controlled, multicentric trials.

CONCLUSION

Vitamin D deficiency is highly prevalent among high-risk Indian TB patients completing first-line treatment, and adjunct cholecalciferol supplementation during and after ATT was associated with a substantial and statistically significant reduction in bacteriologically confirmed TB recurrence at 24 months, in both adults and children. The magnitude of benefit correlated closely with the degree of biochemical correction achieved, supporting a genuine dose-response relationship rather than a chance association. Given its low cost, favourable safety profile, and compatibility with existing programmatic infrastructure, screening for and correcting vitamin D deficiency in high-risk post-treatment TB patients merits serious consideration as an adjunct strategy within India's National TB Elimination Programme. Confirmation through adequately powered, multicentric, placebo-controlled randomised trials is warranted before this approach can be recommended for universal policy adoption.

Conflict of Interest

The authors declare no conflict of interest.

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