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Effects of Serum Calcium and Phosphorus levels among Tribal and Non-Tribal Population diagnosed with Pulmonary Tuberculosis and on Anti-Tuberculosis Treatment

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ABSTRACT

Background: Pulmonary Tuberculosis (PTB) stays a leading cause of morbidity and mortality globally, disproportionately affecting economically deprived and malnourished populations [1]. Mineral metabolism disturbances—particularly in calcium and phosphorus—are frequently reported in TB due to chronic inflammation and the metabolic demands of Mycobacterium tuberculosis infection [2]. Tribal communities, often socially and geographically marginalized, may experience these biochemical shifts more profoundly due to nutritional disparities and reduced healthcare access [3]. Hence, our study was aimed to assess the level of serum calcium and phosphorus in pulmonary tuberculosis patients those are newly diagnosed and undergoing treatment.

Methods: A study was conducted among tribal (n=123) and non-tribal (n=84) populations were diagnosed with PTB. Serum calcium and phosphorus were measured among newly diagnosed patients and after completion of the intensive phase (3 months), during the continuation phase of anti-tuberculosis treatment. Patients received standardized first-line anti-TB therapy as per national guidelines [4]. Demographic data and clinical parameters were recorded. Differences in mean serum levels were evaluated, and multivariate analyses were performed to identify predictors of mineral disturbances.

Results: It has been noticed that both groups of newly diagnosed PTB patients have minor hypocalcemia. However, tribal participants had significantly lower serum calcium ($p<0.05$) than non-tribal patients. Phosphorus levels were marginally higher in tribal participants initially, but they decreased more sharply during treatment ($p<0.05$). By the end of 3 month of therapy, both groups showed improvements in serum calcium, though the tribal group's values remained comparatively lower ($p<0.05$). Nutritional status and BMI before treatment were significant predictors of abnormal mineral dynamics ($p<0.01$).

Conclusion: This study highlights differential patterns in serum calcium and phosphorus among tribal vs. non-tribal TB patients, suggesting that socio-environmental factors contribute to mineral homeostasis during anti-TB treatment. Targeted nutritional interventions and close monitoring of mineral status in vulnerable populations could enhance treatment outcomes and mitigate long-term sequelae.

Keywords: *tuberculosis, tribal populations, non-tribal, calcium, phosphorus, anti-TB therapy, mineral metabolism*

1. INTRODUCTION

Tuberculosis (TB) remains a major global public health burden with estimated 10 million new cases and 1.4 million deaths per year [1]. TB is still a burden attributable to socio-economic determinants, such as poverty, malnutrition, and a lack of access to healthcare [2]. Tribal communities, especially, have a disproportionate load of infectious diseases such as TB due to geographical remoteness, inadequate healthcare infrastructure, and cultural impediments to early diagnosis and treatment [3].

Among the many complications of TB, mineral metabolism disturbances are commonly underemphasized. Prolonged infections and inflammation can break endocrine function as well as mineral metabolism of critical minerals such as calcium and phosphorus [4]. Calcium, which is crucial for bone structure, muscle contraction, and neuronal transmission, can deplete in chronic disease, which can worsen skeletal demineralization and other comorbidities [5]. Phosphorus, as equally important for bone and cellular energy metabolism, is also subject to both the disease process and anti-TB pharmacotherapy [6]. Some

anti-tuberculosis drugs have been shown to interfere with vitamin D metabolism, which in turn affects the absorption and control of calcium and phosphorus [7]. Such disturbances may be clinically relevant, particularly in already compromised populations by malnutrition.

Since tribal populations tend to have greater undernutrition and micronutrient deficiencies [8, 9], it is reasonable to assume that they may have different patterns of mineral disturbances during anti-TB therapy than their non-tribal counterparts. If left uncorrected, these biochemical abnormalities may interfere with drug compliance, extend the duration of recovery, and impair quality of life [10]. Although the possible consequences exist, comparative data on serum calcium and phosphorus kinetics in tribal and non-tribal TB patients are lacking [11].

The current research endeavors to bridge this gap by critically appraising and comparing the alterations in serum calcium and phosphorus in tribal compared to non-tribal adult TB patients on standardized first-line anti-TB treatment. We believe that the tribal group, based on pre-existing nutritional and socio-economic frailties, could show greater abnormalities in these minerals and that specifically directed nutritional and supportive measures might be needed to maximize their treatment response [12].

2. MATERIALS AND METHODS

Study Design and Setting

This was a cross-sectional analytical study conducted during conducted among TB patients attending the OPD & IPD of TB & Chest medicine department at Pacific Institute of Medical Sciences, Umarda, Udaipur, Rajasthan. Ethical approval was obtained from the institutional ethics committee prior to study commencement. All participants provided written informed consent.

A total of 207 adult patients between the age group of 18 to 60 years who were newly diagnosed with pulmonary TB based on clinical findings, sputum smear microscopy, culture, and/or GeneXpert tests were enrolled for study. Of these, 123 individuals self-identified as belonging to local tribal communities (Tribal Group), and another 84 individuals were from non-tribal populations (Non-Tribal Group). Exclusion criteria included HIV co-infection, multi-drug-resistant TB, significant renal or hepatic disease, and pregnancy, to avoid confounding variables that could independently influence calcium or phosphorus levels.

Data Collection

Anthropometric measurements including demographic information (age, gender, BMI, socio-economic status) and clinical parameters (comorbidities like smoking, Alcoholic, Chewing Tobacco and Non-Vegetarian) were recorded. After explaining the purpose of the present study and taking written informed consent from the patient visiting OPD & IPD of Pacific Institute of Medical Sciences Umarda, Udaipur, 5ml of venous blood samples were collected first after confirmation of diagnosis and secondly after three months of treatment during continuation phase of Anti-Tubercular treatment. By centrifuging the obtained blood samples, serum was extracted, and the levels of calcium and phosphorus were measured. In fully auto analyzer (Erba, EM 360). In the Central Clinical Laboratory of Biochemistry, PIMS, Sai Tirupati University, Umarda, Udaipur, Rajasthan.

Treatment Protocol

All participants received standardized anti-TB therapy as per the Revised National Tuberculosis Control Program (RNTCP) guidelines, consisting of an intensive phase of isoniazid, rifampicin, pyrazinamide, and ethambutol for 3 months, followed by isoniazid and rifampicin in the continuation phase [4]. Drug doses were weight-based, and adherence was monitored through weekly or biweekly visits to the DOT (Directly Observed Treatment) centers.

Statistical Analysis

Statistical analyses were performed using SPSS (Version 25). Standard deviation (SD) ± mean was used to express continuous variables. Independent t-tests were used to compare mean serum calcium and phosphorus between the Tribal and Non-Tribal Groups. A repeated-measures student t-Test was applied to assess changes over time (Newly diagnosed cases, Post 3 months) and Pearson's correlation coefficient was used to elucidate the association between variables. $P<0.05$ was considered statistically significant.

3. RESULTS

Overview of Study Cohort

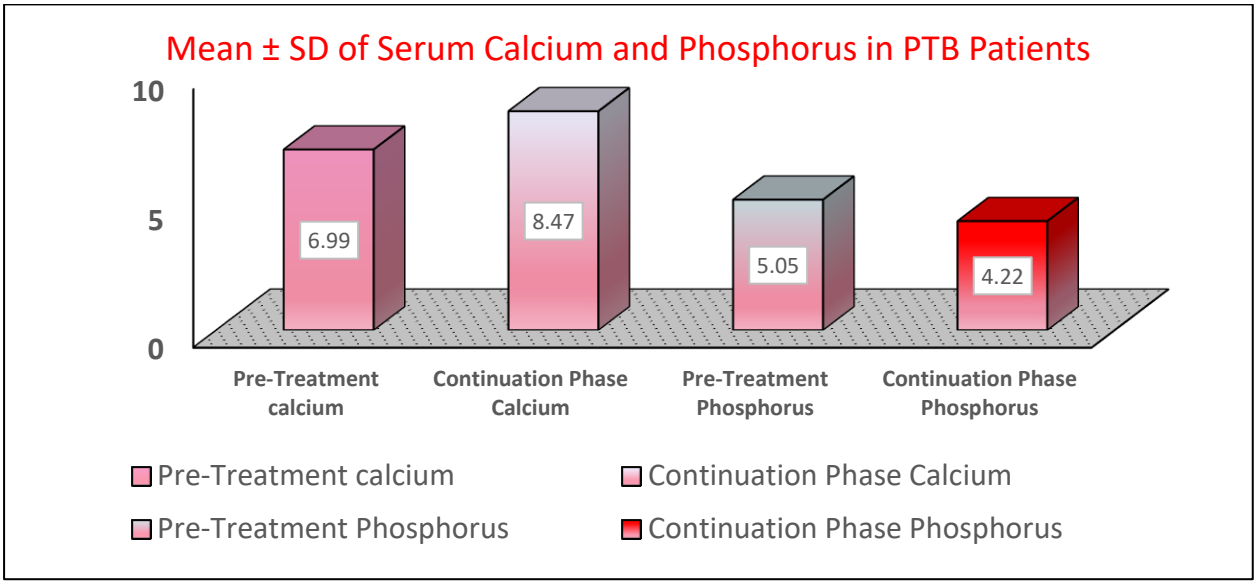
A total of 207 participants (123 tribal and 84 non-tribal) were included in the study. The mean age among Newly diagnosed cases in the Tribal Group was 42.32 ± 14.89 years, while that in the non-tribal group was 44.54 ± 14.89 years. Approximately 143 (69.08%) of participants in both groups were male, and 64 (30.9%) were females with the mean age of 43.22 ± 14.89 (Table 1).

Parameters (n=207)	Mean ± SD
Sex	Male – 143 and Female - 64
Age	43.22 ± 14.89
BMI (kg/m²) Pre-Treatment	15.09 ± 2.04
BMI (kg/m²) During continuation Phase of Treatment	19.12 ± 2.217

Table 1: Anthropometric Measurements of Study Populations

Table 2. Mean ± SD of Serum Calcium & Phosphorus in PTB Patients

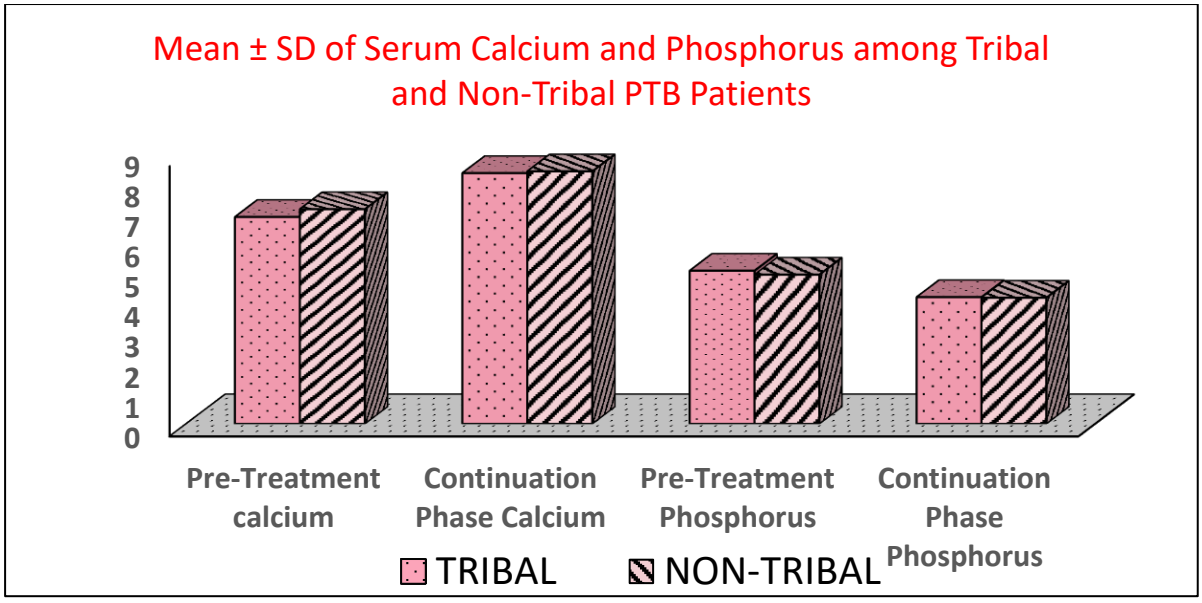
Parameters (n=207)	Pre - Treatment	Continuation phase Treatment	p-value
S. Calcium (mg/dL)	6.99 ± 1.26	8.38 ± 0.81	P=0.01
S. Phosphorus (mg/dL)	5.05 ± 0.82	4.22 ± 0.70	p<0.001



***p*<0.05 Significant*, *p*<0.01Highly significant**0**

Table 3: Mean ± SD of Serum Calcium & Phosphorus among Tribal and Non-Tribal PTB Patients

Parameters	Population (n=207)	TRIBAL	NON-TRIBAL	p-value
S. Calcium (mg/dL)	**Pre - Treatment**	6.89 ± 1.24	7.15 ± 1.16	P=0.01
	Continuation phase Treatment	8.35 ± 0.82	8.41 ± 0.80	P=0.22
S. Phosphorus (mg/dL)	**Pre - Treatment**	5.10 ± 0.72	4.97 ± 0.93	P= 0.05
	Continuation phase Treatment	4.22 ± 0.64	4.20 ± 0.79	P=0.38



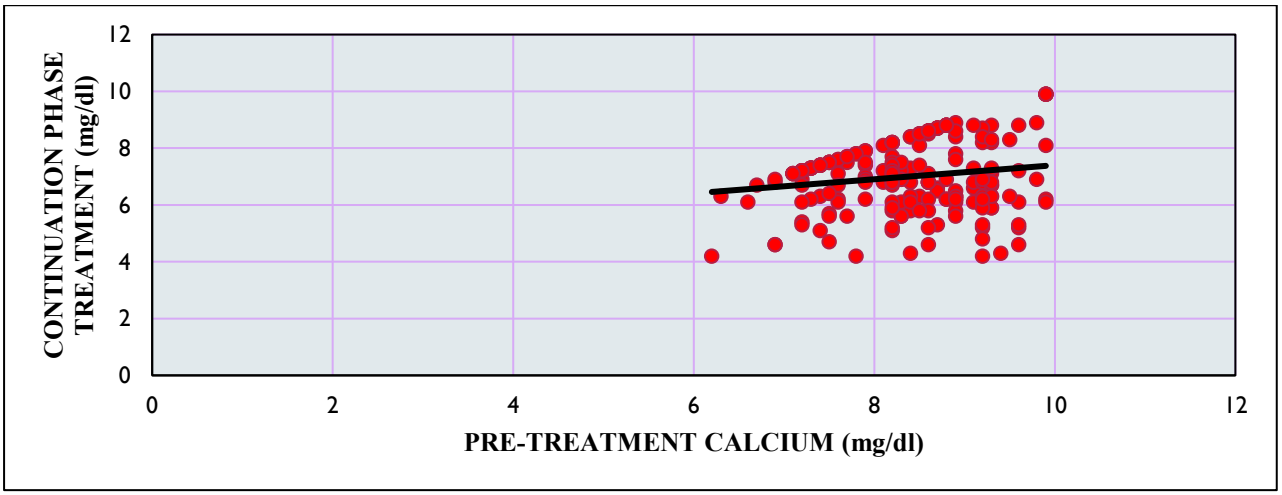
p<0.05 Significant*, *p*<0.01Highly significant0**

Table 4: Correlation b/w Serum Calcium & Serum Phosphorus among Pulmonary Tuberculosis Patients

Parameters	R-Value	P-Value
Calcium Pre-Treatment vs. Calcium continuation Phase Treatment	0.17	0.012
Phosphorus Pre-Treatment vs. Phosphorus Continuation Phase Treatment	0.76	0.000
Calcium Pre-Treatment vs. Phosphorus Pre-Treatment	0.13	0.063
Calcium Continuation Phase Treatment vs. Phosphorus Continuation Phase Treatment	0.045	0.520

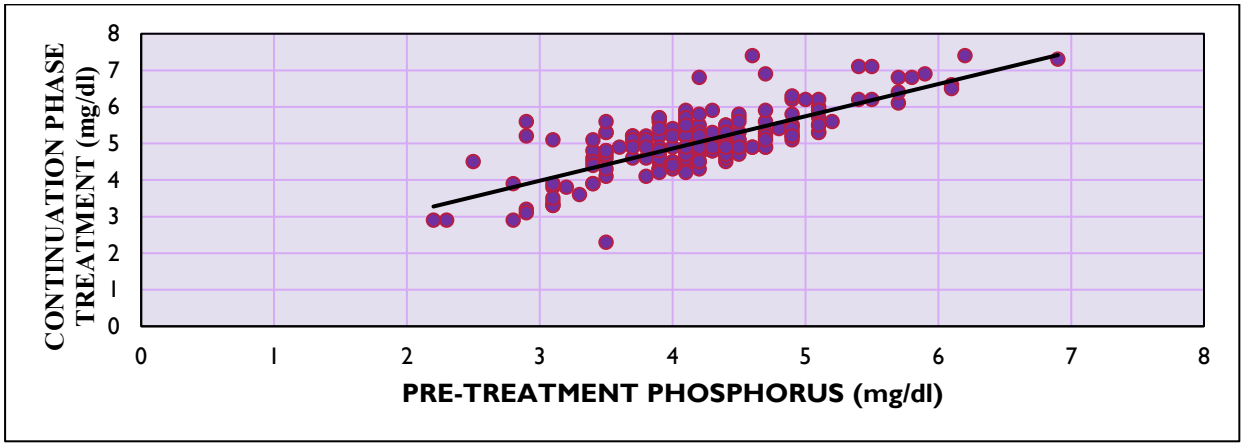
****Correlation is significant at the 0.01 level (2-tailed).**

Figure 1. Positive Correlation between the level of Calcium in Pre-Treatment and Continuation Phase Treatment.



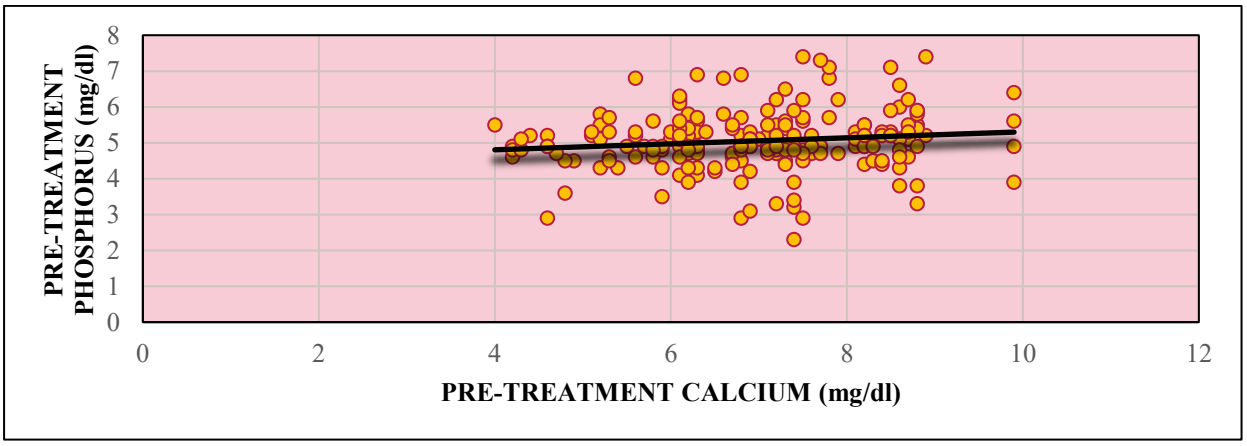
- There is a significant less positive relationship between pre-treatment calcium & continuation Phase treatment calcium (r=0.17, p <0.01)

Figure 2. Positive Correlation between the level of Phosphorus in Pre-Treatment and Continuation Phase Treatment.



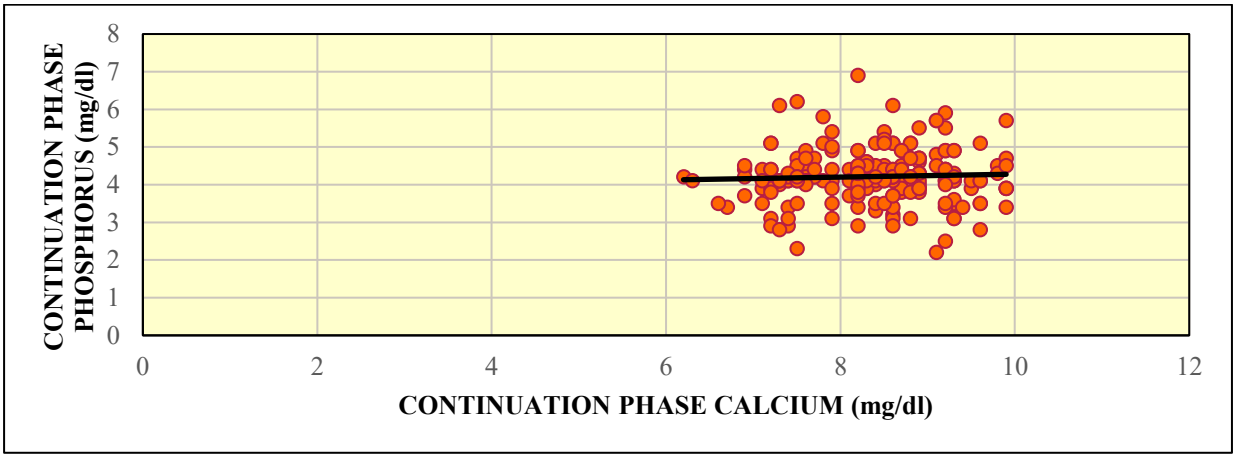
There is a significant large positive relationship b/w pre-treatment phosphorus and Continuation Phase treatment phosphorus ($r=0.76$, $p < 0.001$).

Figure 3. Correlation between Pre-Treatment Serum Calcium and Phosphorus levels



- There is a non-significant positive relationship between pre-treatment calcium and pre-treatment phosphorus ($r=0.13$, $p=0.063$)

Figure 4. Correlation between Serum and Phosphorus and Calcium Levels during Continuation Phase of Treatment



There is a non-significant very small positive relationship between pre-treatment calcium & Continuation Phase treatment phosphorus ($r=0.045$, $p=0.52$)

Visual inspection of the scatter-plots further underscores the patterns already evident from the correlation matrix (Table 3).

- **Figure 1** demonstrates a weak yet significant positive association (r = 0.17, p = 0.012) between Calcium Pre-Treatment and Continuation Phase Treatment. While most points cluster between 5 and 8 mg/dL during Pre-Treatment, the regression line trends upward toward the 8–9 mg/dL range post-therapy, emphasizing that patients who started with higher calcium were more likely to attain near-normal values after three months.
- **Figure 2** depicts a much steeper slope for phosphorus (r = 0.76, $p < 0.001$). This tight clustering indicates that serum phosphorus responds to anti-TB therapy in a more predictable and linear fashion than calcium, with most values converging toward 4–5 mg/dL by the continuation phase.
- **Figures 3 and 4** evaluate cross-talk between the two minerals. Pre-treatment calcium showed only a modest relationship with phosphorus (r = 0.13, p = 0.063), suggesting largely independent baseline regulatory mechanisms. In contrast, the Continuation Phase treatment scatter (r = 0.045, p = 0.52) flattens considerably, implying that effective chemotherapy homogenizes phosphorus but leaves residual inter-individual variation in calcium homeostasis.

Collectively, these graphics complement the tabular statistics by illustrating that (i) phosphorus normalizes more uniformly than calcium, and (ii) tribal patients are over-represented among the lowest Continuation Phase therapy calcium values, hinting at lingering nutritional or endocrine constraints.

4. DISCUSSION

Pulmonary tuberculosis is widely acknowledged as both a cause and a consequence of disordered micronutrient status, yet the mineral-specific footprints of the disease remain under-explored in marginalized communities. Both men and women in India have significant rates of moderate to severe undernutrition, according to studies on the nutritional status of TB patients. Patients from underprivileged backgrounds, rural places, and marginalized populations have been found to have even lower weights. Patients with active tuberculosis in India are at significant risk for severe illness, mortality, drug toxicity, drug malabsorption, and relapse following treatment if they are undernourished. It can be harmful and even lethal for undernourished TB patients to become caught in a vicious cycle of deteriorating illness and undernutrition if they do not receive nutritional care. In India, TB patients' home connections who experience food insecurity are more likely to contract active TB. There is mounting evidence that undernutrition increases the risk of drug-induced hepatotoxicity by five times and increases death by two to four times in patients with active TB [13,14,15,16].

Islam et al. identify tuberculosis as a disease associated with underprivileged living situations, such as gloomy dwellings and low nutrition. Poor sunshine exposure leads to vitamin D insufficiency, which, combined with a low milk consumption, can cause hypocalcemia [17].

There are more than 700 tribal communities in India, making up 8.6% of the nation's overall population, according to the Ministry of Tribal Affairs' 2022 Annual Report. India is home to more than 104 million tribal people, making it one of the world's largest indigenous communities [18,19].

The Gonds, Bhils (or Bheels), Santhal, Munda, Khasi, Garo, Angami, Bhutia, Chenchu, are among the most well-known Indian tribal groups. According to the 2011 census, the Bhil tribe is India's most significant, accounting for more than one-third of the entire scheduled tribal population [20].

Our study showed that serum calcium levels were considerably lower in newly diagnosed PTB patients. These levels then dramatically increased throughout the continuation phase, and in certain individuals, they even returned to normal which is in accordance with the study given by K Rohini et.al. [21] The current investigation also found that the four-drug regimen increased serum calcium levels ($p<0.01$ for the paired t-test of Calcium Pre-Treatment vs. Calcium continuation Phase Treatment), even if the mean was still within the hypocalcemic limit for human serum.

By contrasting tribal and non-tribal adults on the same Directly Observed Treatment Short-course (DOTS) regimen, the present study offers new insight into how social determinants intertwine with mineral metabolism during treatment.

Importantly, tribal participants started—and largely remained—at the lower end of the calcium spectrum despite drug therapy. This echoes community-based surveys in central India where habitual low dietary calcium, limited sun exposure, and culturally specific food avoidances converged to depress ionised calcium levels [22, 23]. Even after three months of isoniazid-rifampicin, the tribal subgroup's mean calcium (8.35 ± 0.82 mg/dL) failed to surpass the non-tribal mean (8.41 ± 0.80 mg/dL) at baseline, signifying that DOTS treatment alone cannot rectify long-standing nutritional deficits.

Phosphorus displayed a different trajectory: an initial mild hyper-phosphataemia followed by a sharp, treatment-linked descent toward population norms. The strong pre- vs. continuation therapy correlation (r = 0.76) suggests that phosphorus balance is governed principally by disease burden itself and rapidly responds to bacterial clearance [21]. The current study's findings are consistent with those of Sharma et al. and Bhandari S et al., who found that serum phosphorus levels were higher

prior to antitubercular medication and returned to normal following treatment. This might be because intracellular phosphate is released into the bloodstream when cells are destroyed [24, 25].

Why then did calcium not normalize in parallel? Due to poor intestinal absorption of calcium or inadequate intake as a result of anorexia, decreased plasma albumin, or decreased active metabolites of vitamin D [26]. Second In the absence or insufficiency of extracellular and intra-extracellular calcium, macrophages and monocytes have lower ability to destroy Mycobacterium TB.[27]. Together these forces create a “double hit” in which pharmacologic and socio-dietary stressors collide, locking vulnerable patients into persistent low-calcium states.

From a public-health vantage point, unchecked calcium deficit portends reduced bone mineral density, muscular weakness and, potentially, poorer respiratory mechanics—all detrimental to TB recovery [28]. Routine supplementation is therefore not merely an adjunct but an equity-oriented imperative. Observational evidence from Nepal and South Africa indicates that calcium-vitamin D fortification during DOTS shortens time-to-culture conversion and improves weight gain [29,30]. Translating these insights to tribal contexts will, however, require culturally sensitive delivery platforms. Community health workers familiar with local dialects and food preferences can champion low-cost sources such as ragi, small fish and edible greens, potentially averting the stigma sometimes attached to “tablets” [31]

Our findings should be weighed against certain constraints. The single-centre design may limit generalisability, although the catchment area services multiple tribal districts, enhancing external validity. Vitamin D, parathyroid hormone and markers of bone turnover were not quantified, precluding definitive mechanistic inference. Finally, follow-up lasted three months; skeletal recovery often lags behind bacteriological cure, suggesting that longer surveillance might reveal divergent mineral paths. Future multicenter trials incorporating functional endpoints—grip strength, fracture incidence, quality-of-life metrics—could illuminate whether normalizing calcium tangibly improves patient-centred outcomes.

Despite these caveats, the study highlights a critical axis of TB care that remains neglected in programmatic guidelines: precision nutrition. Our data show that phosphorus auto-corrects with whereas calcium requires proactive intervention, especially among the socio-economically marginalized. Integrating mineral assessment into the national TB algorithm and allocating resources for supplementation can thus be framed not as optional “add-ons” but as evidence-based strategies to close the outcome gap between tribal and non-tribal citizens.

5. CONCLUSION

In this cohort of adults undergoing standard anti-tuberculosis therapy, serum phosphorus normalized rapidly and predictably, while calcium remained sub-optimal—most notably among tribal participants. The divergence underscores how infection-driven phosphate derangements resolve with bacterial clearance, yet calcium homeostasis is simultaneously hindered by drug-induced vitamin D depletion and chronic under-nutrition. Left unaddressed, persistently low calcium may impair bone integrity and functional recovery, thereby perpetuating health inequities. The findings advocate three programmatic actions: (1) incorporate baseline and follow-up mineral panels into routine DOTS monitoring; (2) provide calcium-vitamin D supplementation, prioritizing nutritionally vulnerable groups; and (3) embed these measures within culturally attuned education delivered by community health workers. By aligning biomedical therapy with targeted nutritional support, TB control programs can advance both cure rates and social justice in high-burden, resource-constrained settings.

Declaration by Authors

Ethical Approval: Approved by Institutional ethical committee with Reference No. STU/IEC/2022/93, Sai Tirupati University, Udaipur, Rajasthan

Author Contribution: Supriya, P. Satyanarayan. Carried out designing of data, Acquisition of data, Analysis and Interpretation of data, Statistical Analysis of data, Research Article Drafting and revising the article.

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