Systematic Review

Malnutrition in tribal people living with tuberculosis in India: A systematic review & meta-analysis

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Background & objectives: Tuberculosis (TB) remains a persistent public health challenge in India. The country also has high proportions of malnutrition in different areas, making the population susceptible to TB. Among vulnerable populations, such as tribal communities, TB and malnutrition pose significant threats. Tribal populations exhibit disproportionately higher TB prevalence rates compared to non-tribal groups. Also, malnutrition prevalence among tribal communities far exceeds national averages in India. Amidst fragmented data, a systematic review of nutritional status among tribal populations with TB in India is imperative to inform comprehensive intervention strategies.

Methods: Cross-sectional, case-control, cohort and interventional studies reporting the nutritional status of active TB affected individuals among tribal populations in India were specifically included if terms such as "malnutrition" or "low BMI" were used. This systematic review followed PRISMA guidelines and was registered with PROSPERO (CRD42020168328). The data was assessed using a random-effects model and standardized mean with 95% confidence interval (CI). The I² statistics indicated heterogeneity. Publication bias was evaluated using funnel plots.

Results: Out of 124 studies, 20 were selected for initial screening, 15 were excluded due to a lack of appropriate data, and five were included for the final analysis. The pooled prevalence estimates of malnutrition among Indian tribes living with TB was 514 per 1000 people, with 95% CI: 232-791. The sensitivity analysis showed that no individual study influenced the estimation of pooled prevalence.

Interpretation & conclusions: In the background of India, contributing considerably to the burden of TB-related morbidity and mortality alongside undernutrition, reviews have underscored undernutrition as the predominant risk factor for TB, affecting over 50 per cent of the population in some States. This situation is exacerbated among the tribal communities in India due to the dual burdens of undernutrition and TB being more pronounced. Our systematic review consolidates evidence from five studies, revealing the prevalence of malnutrition among tribal TB patients. Conducting well-planned implementation research to address this dual burden among the underprivileged population would help achieve the ambitious goal of a TB-free India 2025.

Tuberculosis (TB) remains a major public health problem in India and across the globe. According to the Global Tuberculosis Report, in 2023, the World Health Organization (WHO) areas of South-East Asia accounted for 46 per cent of TB cases in 2022. Of these, India accounted for 27 per cent, which is the highest in the region[1]. According to the report on the National TB Prevalence Survey (2019–2021), the prevalence of TB among the adult population is 316 per 100,000[2]. In many parts of India, individuals with active TB, especially those with pulmonary TB, have coexisting undernutrition, which can be severe and life-threatening. Moreover, undernutrition is considered to be one of the risk factors for TB infection or the progression of latent TB into active TB. Malnutrition is also associated with unfavourable treatment outcomes. As evidenced by the data, the population-attributable fraction of TB due to malnutrition in India is as high as 61.5 per cent in women and 57.4 per cent in men[3]. A report[4] on Indian pulmonary TB patients showed that an increase in body mass index (BMI) lowered the odds of death during treatment [Odds ratio (OR), 0.78 (95% CI: 0.68–0.9) for each unit increase in BMI] after adjustment for age, sex, treatment category, sputum smear and human immunodeficiency virus infection status[4]. A recent modelling study projected that modest reductions in undernutrition could reduce TB incidences by ~4.8 (95% uncertainty range, 0.5 million – 17.1 million) over 20 yr in India[5].

In India, about 104 million tribal people live in different geographical locations (8.6% of the total population) and are distributed among 705 tribes across the nation[6]. A common feature among the tribals in India is that they have poor health indicators, a greater burden of morbidity and mortality, and limited access to health care. The tribals are vulnerable to both TB and undernutrition. A systematic review and meta-analysis on pulmonary TB among tribal in India has shown that the pooled estimate of TB prevalence was 703 per 100,000 population[6].

Malnutrition among tribal people in India, indicated by Chronic energy deficiency (CED), is 60 per cent[7], while it is about 30 per cent among the general adult population in India[8]. Since malnutrition is a major risk factor for TB, strategies on nutritional intervention will be helpful in the efficient control of TB among this underprivileged population. Currently, available data is scattered and misrepresentative. Hence, a systematic review of nutritional status among the tribal population in India is essential to plan a comprehensive

Table I. Inclusion and exclusion criteria using the CoCoPop framework

Component	Inclusion criteria	Exclusion criteria
Condition	Malnourished or those with low BMI	Malnourished or low BMI is not quantified
Context	Indian tribal people diagnosed with TB No time/period restrictions	TB is not a primary variable
Population	Tribal people living in India	Non-tribal populations in India Article not published in English

TB, tuberculosis; BMI, body mass index

intervention strategy. The End TB strategy[9] of WHO aims to decrease TB incidences by 90 per cent and deaths due to TB by 95 per cent by 2035, which is unlikely to succeed without targeting undernutrition. Therefore, the present systematic review is planned to generate the required information.

Material & Methods

This systematic review was carried out following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (registered with PROSPERO (CRD42020168328). No ethical approval was sought as this analysis is undertaken from previously published data.

Identification and eligibility of studies: We reviewed community-based studies that targeted the tribal population and included people aged ≥15 yr in order to ascertain the prevalence of malnutrition among the tribal population living with TB in India. Studies describing malnutrition were specifically included if the terms such as 'malnutrition' or 'low BMI' were used. As our inclusion criteria were restricted to studies that reported malnutrition or low BMI, it was crucial to consider additional aspects when evaluating the quality and dependability of the investigations. These considerations included study design, sample size and data collection methods.

Selection criteria: The search strategy was formulated according to the CoCoPop (condition, context and population) framework, which is recommended for systematic reviews of prevalence studies (Table I). We included the following studies for the analysis: cross-sectional, case-control, cohort study design

and interventional study design reporting the baseline nutritional status of those with active TB. The main outcome considered was the prevalence of malnutrition in a tribal population living with TB in India. A low BMI was an indication of malnutrition. BMI was calculated by dividing a person's weight in kilograms by the square of their height in meters. Only studies on people living with TB from Indian tribal communities were included.

Search criteria: For meta-analysis, we included all population-based cross-sectional and cohort studies. A literature search was conducted in PubMed, Cochrane Library and Google Scholar using the following combination of keywords: 'pulmonary tuberculosis', 'tribals', 'nutrition', 'India' and 'prevalence'. Only published articles in the language 'English' were included in this meta-analysis. The references cited in the retrieved articles were also reviewed, and those found relevant were selected. Two independent reviewers screened the title/abstract and full text using Rayyan QCRI[10].

Critical appraisal: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement was used to evaluate the quality of reporting[11]. Two reviewers worked on it. Discussion among the reviewers was used to settle disagreements, and when that was not feasible, a third reviewer took over.

Statistical analysis plan: A summary of reports on the prevalence of malnutrition among the tribal people living with TB was done using R software (Version. 4.4.1 for Windows) [12]. Meta-analysis of prevalence data was analyzed, pooled and estimated with a 95 per cent confidence interval (CI) using the 'metafor' package of R software[13]. Forest plots displayed prevalence with corresponding 95 per cent CIs for each study. The overall random-effects pooled estimate with its CI is reported in this paper. Due to the nature of the studies, substantial heterogeneity was expected. Hence, a random-effects meta-analysis was done with the estimate of heterogeneity being taken from an inverse-variance model[14]. Publication bias was assessed using Egger's test, as well as a visual inspection of the funnel plot. Between-study heterogeneity was evaluated using Higgin's I^2 and Cochran's Q method; I^2 values of 25, 50 and 75 per cent were considered low, moderate and high heterogeneity, respectively[15]. A χ^2 for Q determined the significance of heterogeneity, and a $P<0.05$ was considered significant. The impact of any single study on the overall results was assessed using
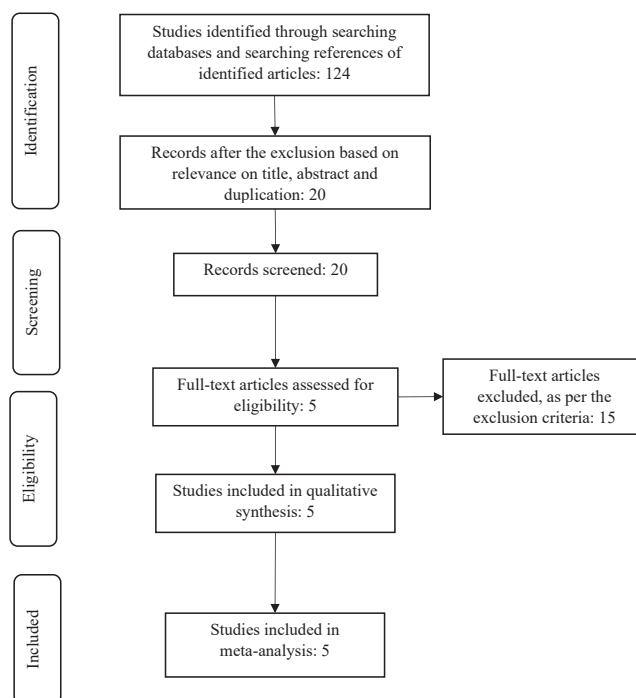
Fig. 1. PRISMA flow diagram showing the process of study selection.

a leave-one-out sensitivity analysis, in which each study was iteratively removed, and the findings were compared to the overall meta-analysis.

Results

We collected 124 articles as per the search criteria. They were all screened based on title and abstract, from which 20 articles were shortlisted for review. Three studies were excluded upon preliminary scrutiny as they did not fulfil the inclusion criteria. Eight articles provided secondary data related to the study's objective; nevertheless, a detailed review showed that the information provided in those articles was irrelevant and, hence, excluded. Another four articles were not included since they did not carry information on malnutrition among tribal people living with TB (Fig. 1). Assessment specifics of studies is shown in Table II[16-20].

Included studies: Five publications fulfilling the study's requirements were considered for analysis since they reported on two necessary factors: malnutrition and TB among Indigenous people. The majority of studies used bacteriological tests such as sputum smear and culture examination as confirmatory procedures for TB. The details of people living with TB were acquired from both survey data in the tribal areas and TB treatment facilities. Anthropometric data were used to determine

Table II. Assessment of quality of studies according to STROBE criteria

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Bhat *et al*[16] (2017)																				
√	√	√	√	√	√	√	√	*	√	√	√	√	√	√	√	√	√	√	√	√
Tungdim *et al*[19] (2008)																				
√	√	√	√	√	√	√	√	*	√	√	√	√	√	√	√	√	*	√	√	√
Tungdim *et al*[20] (2010)																				
√	√	√	√	√	√	√	√	*	√	√	√	√	√	√	√	√	*	√	√	√
Bapat *et al*[18] (2015)																				
√	√	√	√	√	√	√	√	*	√	√	√	√	√	√	√	√	√	√	√	√
Rao *et al*[17] (2018)																				
√	√	√	√	√	√	√	√	*	√	√	√	√	√	√	√	√	√	√	√	√

Note: 1. Title & abstract; 2. Introduction/background; 3. Objectives; 4. Study design; 5. Setting; 6. Participants; 7. Variables; 8. Data; 9. Bias; 10. Study size; 11. Quantitative variables; 12. Statistical methods; 13. Descriptive data; 14. Outcome data; 15. Main results; 16. Other analyses; 17. Key results; 18. Limitations; 19. Interpretation; 20. Funding
√, Good description; %, Partial description; *, No description

malnutrition in all five articles. Their characteristics are briefed in Table III.

A case-control study conducted in Gwalior, India (March-November 2013) on the Saharia community (n=10259) revealed 267 TB cases, with 228 being underweight. This underscores targeted advocacy needs for nutritional interventions among tribal TB patients[16]. In a 2013–2014 cross-sectional study[17] in Shivpuri, Madhya Pradesh, 220 pulmonary TB cases and 660 controls were analyzed. The findings highlighted substantial correlations in Saharias between pulmonary TB risk and undernutrition[17].

A study[18] conducted in Maharashtra, India (May 2009-June 2011) focused on Melghat tribal community members with TB, where morbidity and mortality are primarily due to TB and malnutrition. Out of 275 individuals, 91.6 per cent were underweight (BMI < 18.5), with 70.2 per cent showing low diet intake and 33.7 per cent were severely malnourished. Among malnourished individuals, 32 exhibited *Mycobacterium* TB (M. tb) positivity[18].

In Manipur, northeastern India, two studies on tribal individuals with TB included a cross-sectional and a case-control study at four TB facilities involving 247 adult males. Participants, categorized by treatment stage, exhibited improved post-therapy nutritional status, evidenced by decreased percentages of low BMI (<18.5 kg/m^2) in affected individuals before starting treatment (64.5%), those who had completed two months of treatment (49%), and after completing treatment (34%) groups, compared to controls (6.3%). The study underscores enhanced nutritional outcomes following TB treatment, as demonstrated by various anthropometric indices[19].

A case-control study[20] conducted in Manipur, India (August 2000-July 2001) focused on adult TB affected individuals (20-40 yr). Of 108 cases with standard treatment, 46 were underweight. Anthropometric measurements revealed higher CED (42%) and undernourishment (64.8%) among TB affected individuals compared to controls, indicating compromised nutritional status with pulmonary tuberculosis onset involving muscle and fat loss[20].

Meta-analysis: A random-effects meta-analysis was conducted because of expected variations between the studies. The meta-analysis indicated that variability between studies was high (T^2 = 0.11; heterogeneity I^2 = 99% with heterogeneity chi-square = 358.92, degrees of freedom (DF) = 4 and *P*<0.01). Our calculations indicated that 99 per cent of the variation observed in the pooled estimate was due to heterogeneity among the studies. Individual study prevalence estimates of malnutrition ranged from 8.6 to 89.6 per cent. Each study was given approximately equal weightage, ranging from 19.8 to 20.1 per cent, due to high heterogeneity between studies. Based on the random effects model, the pooled estimate of the prevalence of malnutrition was 514 per 1000 people infected with TB in the tribal population with a 95 per cent CI: 232–791. The *P*<0.01 indicates that the heterogeneity of the pooled results

Table III. Characteristics of included studies

Study ID	Author	Year	State	Tribe name	Study design	Study start	Study end	Sample size	Tribal population	Mean age (yr)	TB cases	Malnourished with TB	Nutritional status assessment method
1	Bhat *et al*[16]	2017	Madhya Pradesh	Saharia	Case-control	March 13	Nov 13	12123	10259	39.4	267	228	BMI
2	Bapat *et al*[18]	2015	Maharashtra	Korku	Prospective cohort	May 9	Jun 11	419	N/A	N/A	252	32	BMI
3	Tungdim *et al*[19]	2008	Manipur	Mongoloid	Cross-sectional	N/A	N/A	247	N/A	N/A	167	88	BMI
4	Tungdim *et al*[20]	2010	Manipur	Mongoloid	Prospective case-control	Aug-00	July 1	228	N/A	N/A	108	46	BMI
5	Rao *et al*[17]	2018	Madhya Pradesh	Saharia	Cross-sectional	Nov 13	Oct 14	10300	9964	39.7	220	141	BMI

N/A, not available

was significant. A forest plot with the pooled estimate (marked as a diamond with a vertical dotted line) with a 95 per cent CI, as obtained from the random effects model, is displayed in Figure 2. Also depicted are the estimates of the prevalence of malnutrition among the TB positives from the individual studies (marked as circles), along with their 95 per cent CIs.

Publication bias: An attempt was made to assess the publication bias using a funnel plot and Begg's and Egger's test. However, the funnel plot method and other tests were underpowered due to a small number of studies. However, the result of effect estimates against its standard error was plotted and Egger's test showed that it did not indicate the presence of funnel plot asymmetry with a *P* value of 0.834 (Fig. 3).
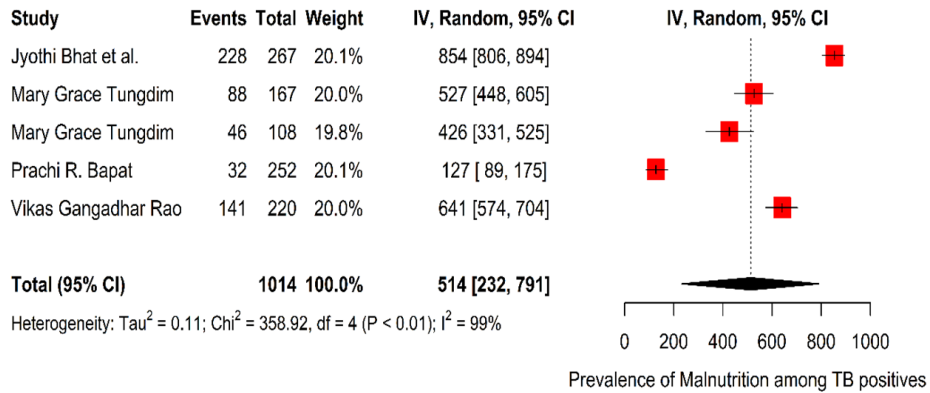
Sensitivity analysis: A sensitivity analysis was performed, which indicated that there was no influence of an individual study on the estimation of pooled prevalence. The resulting pooled estimate still fell within the 95 per cent CI of the original pooled estimate, even after the removal of any specific study at a time. This indicated the stability of our results. Heterogeneity among studies persisted. The sensitivity analysis is graphically depicted in Figure 4, where the vertical dotted line is the actual pooled estimate, we calculated using the random effects model along with its 95 per cent CI.

Discussion

TB is not only a public health crisis but also a socioeconomic catastrophe. India has the largest global burden of TB-related morbidity and mortality, as well as undernutrition. This situation has compounded the effect of TB as indicated by a recent review, which showed that the most significant risk factor for TB in India is undernutrition, which affects more than 50 per cent of the population in most States[21].

The current systematic review has summarized the results from five different studies on TB and malnutrition in the tribal population. The meta-analysis showed that the overall prevalence of malnutrition among those with TB in the tribal population is 514 per 1000 (95 per cent CI: 232,791). High heterogeneity between the studies was observed with heterogeneity $l^2 = 99$ per cent and heterogeneity chi-square=358.92.

In conclusion, our work adequately established the high prevalence of undernutrition among the TB patients of the tribal populations in India. There

Study	Events	Total	Weight	IV, Random, 95% CI	IV, Random, 95% CI
Jyothi Bhat et al.	228	267	20.1%	854 [806, 894]	
Mary Grace Tungdim	88	167	20.0%	527 [448, 605]	
Mary Grace Tungdim	46	108	19.8%	426 [331, 525]	
Prachi R. Bapat	32	252	20.1%	127 [89, 175]	
Vikas Gangadhar Rao	141	220	20.0%	641 [574, 704]	
Total (95% CI)		**1014**	**100.0%**	**514 [232, 791]**	

Heterogeneity: Tau^2 = 0.11; Chi^2 = 358.92, df = 4 (P < 0.01); I^2 = 99%
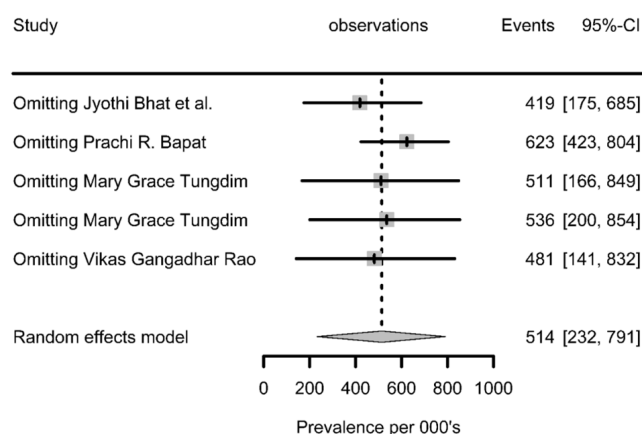
Prevalence of Malnutrition among TB positives

Fig. 2. The forest plot visualization of malnutrition prevalence among TB affected individuals with 95% CI per 1000 population. Weight refers to the weightage given to each study for statistical analysis. IV, random 95% CI refers to an inverse-variance random-effects model with a 95% CI. CI, confidence interval.
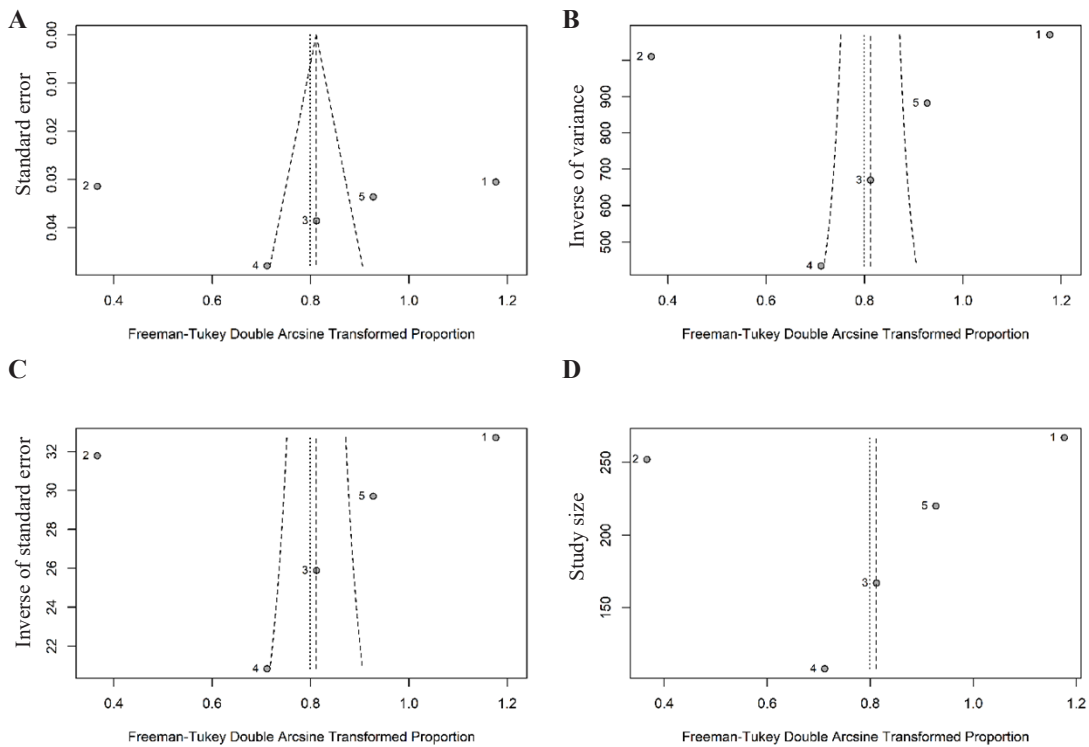
Fig. 3. Funnel plot to show asymmetry of logit transformed prevalence against **(A)** standard error, **(B)** inverse of variance, **(C)** inverse of standard error and **(D)** study size. Egger's test does not indicate the presence of funnel plot asymmetry (P = 0.834).

is a need for implementation research among the tribal population in terms of prevention, diagnosis and treatment. A recent cluster randomized trial in Jharkhand, India, which consisted of two thirds tribal population, showed that the effect of nutritional support on TB incidence in household contacts was associated with a substantial (39-48%) reduction in TB incidence in the household during the two yr of follow up. Such biosocial interventions will accelerate TB control in communities with TB and undernutrition[22].

The Ministry of Health and Family Welfare and the Ministry of Tribal Affairs announced the Tribal TB Initiative[23] on 26 March 2021 to address TB in India's tribal populations, which are known to have a higher prevalence of the disease than the general population[24]. The Government of India's *Nikshay Poshan Yojana* (NPY) is a Direct Benefit Transfer scheme under the National Tuberculosis Elimination Programme (NTEP), which offers INR 500 monthly to all notified patients with TB for nutritional support during the

Fig. 4. A sensitivity analysis plot of malnutrition prevalence estimates with 95% CI per 1000 tuberculosis positive population (after omitting studies one after another).

period of anti-TB treatment. A study has shown that the coverage of NPY among patients with TB had increased and the time to receipt of benefit had halved in the past five yr[25]. However, the policy implications should go beyond endorsing nutrition supplementation alone and promote ongoing initiatives to tackle issues such as hunger, poverty, unemployment, inequality and systemic disadvantage.

The strength of this systematic review is that the included studies were selected after a thorough quality assessment. However, this systematic review has some limitations. First, there is a limited number of articles, making the data insufficient to draw a strong conclusion. Second, the study population was only from three States in India, which may not be representative of the diverse tribe population and age groups across the country, and also required inputs using different screening platforms. Therefore, the results may be over- or underestimated among the included studies. Finally, the funnel plot suggests the existence of publication bias, so our results must be interpreted with caution. Despite the limitations of our review, it summarises the prevalence of undernutrition among tribal communities living with TB and could be used as a reference for future studies.

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