Frequency and Impact of Micronutrient Deficiencies in Patients with Active Pulmonary Tuberculosis

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A B S T R A C T

Background: Active pulmonary tuberculosis (TB) is a leading infectious disease, particularly prevalent in low-income countries like Pakistan. Micronutrient deficiencies, including vitamins A, C, D, E, and minerals such as zinc and iron, are commonly observed in patients with active TB. These deficiencies may compromise immune response, slow recovery, and worsen disease outcomes.

Objective: To evaluates the micronutrient status of Pakistani patients diagnosed with active pulmonary DS-TB and explores the correlation between deficiency levels and disease progression.

Methodology: A cross-sectional study was carried out at the DOTS center District Headquarter Hospital, Haripur. About 200 active DS-TB patients' sample between January 2021 and January 2022 are process by collected blood samples under fasting conditions to avoid dietary influences. Measurement of specific micronutrients (e.g., vitamins A and D) High-Performance Liquid Chromatography (HPLC) method are used while for minerals like iron, zinc, and selenium Colorimetric Assay methods are apply.Additional inflammatory markers (e.g., CRP) to correlate with disease severity and micronutrient levels. For data analysis SPSS software (version 27) is used.

Results: The study had 200 active TB patients in which the mean age was approximately 36 years, with a slight majority of male patients (60%) with low socioeconomic backgrounds (75%). Sputum smear grading further classifies these positive cases by the density of Acid-Fast Bacilli (AFB) in which 1+ (32.5%) had greater frequency. Vitamin D deficiency was most prevalent, affecting 70% of patients, which is concerning given its role in immune function. The correlations between various micronutrient levels and clinical indicators of TB severity, as well as inflammation (measured by CRP levels) in which Vitamin D levels were the most strongly correlated with both TB severity and CRP levels, indicating that deficiencies in Vitamin D are linked to worsened TB symptoms and increased inflammation.

Conclusion: These findings underscore the need for integrated nutritional support in TB treatment protocols to improve patient outcomes and reduce TB morbidity in Pakistan. Enhanced focus on dietary interventions and supplementation may aid in managing TB in this vulnerable population.

Keywords: Micronutrient; TB; Pakistan

Introduction

Tuberculosis (TB) is still one of the most common infectious illnesses in the world, and it has a big influence on public health in low- and middle-income nations. One of the top five nations with the highest burden of tuberculosis is Pakistan, where the healthcare system is strained by high incidence and prevalence rates.[1] Factors including widespread hunger, restricted access to healthcare services, and socioeconomic inequalities make the fight against tuberculosis in Pakistan even more difficult. As a cause and effect of tuberculosis, malnutrition can worsen the illness and make recovery more difficult. Poor micronutrient status is one of the important yet sometimes disregarded manifestations of malnutrition in TB patients.[2]

Micronutrients, which are vitamins and minerals needed in trace levels, are essential for energy production, cellular repair, and immune system function. A strong immune system is necessary for TB patients to manage and eradicate Mycobacterium tuberculosis, the bacterium that causes the illness.[3] However, studies have revealed that important micronutrient deficits, such as those in vitamins A, D, C, E, zinc, and iron, are common in TB patients. Weakened immunological responses, longer healing periods, a higher chance of complications, and even greater death rates are linked to these inadequacies.[4] Due to dietary restrictions, cultural customs, and financial obstacles that restrict access to a variety of nutrient-dense foods, these micronutrient deficits may be very severe in Pakistan.

Numerous variables contribute to the association between tuberculosis and inadequate nutritional status. TB frequently results in nausea, malaise, and appetite loss, which lowers food consumption. Furthermore, during a TB infection, the body has higher metabolic demands, which increases the requirement for nutrients to support tissue repair and the immunological response. Deficits in vital vitamins and minerals can result in poor treatment outcomes and compromised immune function in this state of increased demand.[5] Furthermore, deficits in some micronutrients, such as zinc and vitamin D, may have a direct impact on the severity of the disease because they are known to be important in the immunological response to Mycobacterium tuberculosis.[6]

Many TB patients in Pakistan may not be getting enough nutrients from their diet, especially when it comes to micronutrients. Low-income areas' traditional diets may be high in basic foods like bread and rice, but they frequently lack fruits, vegetables, and protein sources that are important sources of vitamins and minerals. Furthermore, access to a balanced diet may be further limited by cultural norms and financial constraints, which could exacerbate micronutrient deficits in susceptible groups.[7]

Research on micronutrient status in TB patients is scarce in Pakistan, despite its well-established significance. Closing this gap is essential since micronutrient intake-enhancing therapies may be an affordable means of improving TB treatment results. Zinc supplementation has been linked to improved treatment adherence and a quicker recovery, while vitamin D supplementation has demonstrated promise in increasing immunity and enhancing recovery in TB patients.

With an emphasis on the frequency and severity of vitamin and mineral deficiencies that are essential for immune system function and recovery, this study attempts to assess the micronutrient status of active pulmonary TB patients in Pakistan.

Objective

To promote targeted nutritional treatments that can supplement TB treatment regimens by shedding light on the particular dietary gaps faced by TB patients in Pakistan.

Methodology

Between January 2021 and January 2022, a cross-sectional study was carried out at the DOTS center the District Headquarter Hospital, Haripur. Individuals aged 18 and older who have been diagnosed with active pulmonary tuberculosis (TB) through sputum testing and blood testing by taking samples under fasting conditions to avoid dietary influences. Measurement of specific micronutrients (e.g., vitamins A, D; minerals like iron, zinc, and selenium) by High-Performance Liquid Chromatography (HPLC) and Colorimetric Assay methods respectively. Additional inflammatory markers (e.g., CRP) to correlate with disease severity and micronutrient levels. Exclusion criteria include patients with comorbid conditions that impact micronutrient levels (e.g., HIV, renal disease) or those taking supplements that may affect results, while inclusion criteria include patients with active pulmonary tuberculosis who are undergoing treatment or who have recently been diagnosed. Data about 200 active TB patients, including age, gender, socioeconomic status, food habits, and lifestyle factors, are gathered. All statistical analyses were conducted using SPSS software (version 27).

Results

A total 200 active TB patients are enrolled during study period as shown in table 1 demographic and clinical characteristics of the study participants. The mean age was approximately 36 years, with a slight majority of male patients (60%). Most patients (75%) were from low socioeconomic backgrounds, which may correlate with malnutrition. A significant portion (35%) of patients reported being smokers, a factor that could influence

Table 1. Demographic and Clinical Characteristics of TB Patients (N=200)

Characteristic	Frequency (%) / Mean ± SD
Age (years)	35.6 ± 11.2
Gender	
Male	120 (60%)
Female	80 (40%)
Socioeconomic Status	
Low	150 (75%)
Middle	40 (20%)
High	10 (5%)
Smoking Status	
Smoking	70 (35%)
Non-smokers	130 (65%)
Duration Since Diagnosis	3.2 ± 1.8 months

nutrient absorption and TB severity.

The table presents the results of sputum smear testing for 200 patients with active TB. Sputum smear grading further classifies these positive cases by the density of Acid-Fast Bacilli (AFB) in which Scanty (27.5%) had a low bacillary load, with only a few AFB visible per 100 fields.1+ (32.5%) had a moderate number of bacilli, suggesting active TB but with a slightly lower bacillary load. 2+ (22.5%) had higher bacillary counts, indicating more infectious cases and 3+ (17.5%) showed high bacillary loads, suggesting advanced infection stages with greater potential for transmission.

Table 3 summarizes the levels of key micronutrients and the prevalence of deficiencies among the 200 TB patients.

Vitamin D deficiency was most prevalent, affecting 70% of patients, which is concerning given its role in immune function. Selenium and zinc deficiencies were also high, at 60% and 55%, respectively, highlighting the need for nutritional interventions. The average levels of each micronutrient indicate that many patients fell below the optimal thresholds, suggesting that active TB patients in this population are highly susceptible to micronutrient deficiencies.

Table 4 shows the correlations between various micro-nutrient levels and clinical indicators of TB severity, as well as inflammation (measured by CRP levels). Vitamin D levels were the most strongly correlated with both TB severity and CRP levels, indicating that deficiencies in

Table 2. Sputum Smear Results for Active TB Patients (N=200)

Positive smear fields	Frequency (n)	Percentage (%)
Scanty (1-9 AFB/100 fields)	55	27.5%
1+ (10-99 AFB/100 fields)	65	32.5%
2+ (1-10 AFB/field)	45	22.5%
3+ (>10 AFB/field)	35	17.5%

Table 3. Micronutrient Levels and Deficiency Prevalence in TB Patients (N=200)

Micronutrient	Mean Level ± SD	Deficiency Threshold	Deficiency Prevalence (%)
Vitamin A (µg/dL)	25.6 ± 5.4	< 20 µg/dL	45%
Vitamin D (ng/mL)	15.3 ± 4.8	< 20 ng/mL	70%
Zinc (µg/dL)	65.2 ± 10.1	< 70 µg/dL	55%
Selenium (µg/L)	70.5 ± 12.4	< 80 µg/L	60%
Iron (µg/dL)	75.8 ± 15.2	< 85 µg/dL	50%

Vitamin D are linked to worsened TB symptoms and increased inflammation. Similar but weaker correlations were observed for Vitamin A, zinc, selenium, and iron. These findings suggest that lower levels of certain micronutrients may exacerbate TB severity, potentially through increased inflammation. T-test are used for comparing micronutrient levels across categories of TB severity (e.g., mild, moderate, severe). Significance level set at p < 0.05. calculates the p-value automatically when running correlation or regression analyses. The p-value indicates the probability of observing the correlation by chance.

Discussion

Micronutrients are crucial for immune cell activity, inflammation control, and pathogen clearance. For TB patients, adequate levels of these nutrients can support recovery, enhance treatment efficacy, and reduce complications. However, malnutrition and micronutrient deficiencies are common in TB patients, especially in high-burden regions, exacerbating disease severity and hindering recovery.[8]
The study's demographic and clinical findings reflect patterns observed TB-endemic, low- and middle-income countries, emphasizing the impact of socioeconomic factors, age, and gender on TB prevalence. The mean age of the participants in our study was approximately 35.6 years, indicating that TB primarily affects individuals in their productive years. This finding is consistent with data from studies in India, where researchers found that TB is most prevalent among adults aged 20-40 years.[9] This age group is often the most economically active, meaning TB can have significant economic impacts, both on individuals and communities, due to loss of income and productivity.

Also study findings show a higher prevalence of TB in males (60%), aligning with findings from countries with similar TB burdens. A study from Bangladesh reported that males constituted about 65% of TB cases, which is partly explained by gender-related factors. Males are more likely to be exposed to environmental and occupational risks associated with TB, such as smoking, mining, and industrial labor. Additionally, in many regions, cultural factors may limit women's access to healthcare, leading to under-diagnosis in females.[10] However, addressing TB in both genders remains essential, especially since women may face barriers in accessing treatment due to social and financial constraints.

The data showed that 75% of the participants were from low socioeconomic backgrounds. This trend is widely reported in TB research. A study in Nigeria found that low-income groups had a significantly higher prevalence of TB due to factors such as poor nutrition, crowded living conditions, and limited healthcare access. Low socioeconomic status is a critical risk factor as it can compromise immunity, increase exposure to infectious settings, and limit access to timely medical care.[11] In this study, 35% of TB patients were smokers, a finding consistent with similar studies in TB-prevalent areas. A meta-analysis demonstrated that smokers have twice the risk of developing active TB compared to non-smokers,

Table 4. Correlation of Micronutrient Deficiencies with TB Severity and Inflammatory Markers

Variable	Vitamin A	Vitamin D	Zinc	Selenium	Iron
TB Severity	-0.35	-0.42	-0.31	-0.28	-0.26
CRP Levels	-0.40	-0.38	-0.34	-0.30	-0.33
Note: p < 0.05, p < 0.01.					

primarily because smoking weakens lung immunity, making it more susceptible to infection. Additionally, smokers with TB are more likely to experience disease complications and poor treatment outcomes.[12]

The average time since diagnosis was 3.2 months, suggesting a possible delay in diagnosis, as the majority of TB cases are diagnosed when symptoms are already present. In high-burden countries, TB is often detected late due to limited access to healthcare facilities, financial constraints, or low awareness of symptoms. For example, a study in Ethiopia found similar delays, with most patients diagnosed several months after symptom onset.[13] 32.5% of sputum positive cases had a low bacillary load (scanty or 1+ grading), suggesting early-stage disease or cases with a lower transmission risk. This finding is supported by research in Ethiopia where about 33% of patients with positive sputum results had low bacillary counts.[14]

The high deficiency rates of essential nutrients, particularly Vitamin D (70%), Zinc (55%), and Selenium (60%), align with findings from other studies in South Asia. A study in India also identified high rates of Vitamin D and Zinc deficiencies among TB patients, with deficiency rates of 65% and 58%, respectively. The comparable findings indicate that patients in TB-endemic areas, particularly in resource-limited settings, frequently suffer from critical nutrient deficiencies, which may impair immune response and hinder TB recovery.[15]

The strong negative correlation between Vitamin D levels and TB severity (r = -0.42, p < 0.01) in this study is consistent with research from East Africa, reported that low Vitamin D levels were associated with more severe TB symptoms and delayed recovery. Vitamin D plays an immunomodulatory role, enhancing macrophage response and facilitating mycobacterial clearance.[16] This supports the need for Vitamin D supplementation as a potential adjunct therapy for TB patients, particularly in high-burden countries like Pakistan.

Zinc deficiency (55%) was strongly correlated with both TB severity and inflammation, as observed in other studies. Research in Bangladesh showed that Zinc supplementation reduced infection severity and enhanced recovery in TB patients. Zinc is known to contribute to immune cell function and cytokine production, both of which are essential in TB control.[17]

Selenium, an antioxidant micronutrient, was deficient in 60% of patients and correlated with both TB severity and CRP levels (r = -0.30, p < 0.05). A study in Nigeria similarly highlighted the role of Selenium in reducing oxidative stress, which is often elevated in TB patients due to chronic inflammation. Selenium's antioxidant properties may help counteract cellular damage in TB and improve recovery, underscoring the need for its inclusion in nutritional interventions.[18]

Iron deficiency was present in 50% of patients, potentially exacerbated by chronic inflammation that hampers iron absorption. A study in Ethiopia by reported similar iron deficiency rates and found that anemia was common among TB patients. Since iron is essential for red blood cell formation and immune function, deficiency can contribute to fatigue and worsen TB symptoms. However, iron supplementation in TB treatment must be carefully monitored due to concerns that excess iron may fuel bacterial growth.[19]

The high rates of multiple micronutrient deficiencies among TB patients in this study support the need for comprehensive nutritional assessments and interventions as part of TB management, similar to recommendations from the World Health Organization. Implementing fortified food programs or providing targeted supplementation for TB patients could help improve immune function, reduce disease severity, and accelerate recovery rates.

Conclusion

The study reveals a high prevalence of micronutrient deficiencies among TB patients, with implications for TB severity and inflammation. These findings align with global studies in resource-poor settings, suggesting that micronutrient supplementation may enhance TB treatment outcomes. Addressing nutritional deficiencies should be prioritized in TB programs, especially in high-burden countries like Pakistan, to support effective disease management and recovery.

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