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Original Research Article

Serum Zinc Levels in Pediatric Tuberculosis: A Case-Control Study on Nutritional and Clinical Correlations

Glady Muriankeril Varghese[1], Nikil Sam Varughese[2]

[1]Assistant Professor, Department of Pediatrics, Sree Ayyappa Medical College and Research Foundation, Vadasserikkara, Kerala

[2]Associate Professor, Department of General Medicine, Sree Ayyappa Medical College and Research Foundation, Vadasserikkara, Kerala

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Corresponding Author: Dr. Glady Muriankeril Varghese

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Abstract:

Background: Tuberculosis (TB) remains a major global health challenge, particularly in low- and middle-income countries, with India bearing the highest burden of cases worldwide. Zinc, an essential micronutrient crucial for immune function, has been implicated in TB susceptibility and treatment outcomes, yet its role in pediatric TB remains underexplored.

Objectives: The primary objective of the study was to estimate the levels of serum zinc among patients with childhood pulmonary tuberculosis and TB lymphadenitis. The secondary objectives were to determine the correlation between serum zinc levels and patients' nutritional status, clinical type of TB and duration of ATT.

Methods: This was a hospital-based case control study conducted in the Department of Paediatrics, Vinayaka Missions Medical College and Hospital, Karaikal, over a two-year period from August 2016 to June 2018.

Results: The study evaluated serum zinc levels among 48 children with tuberculosis (cases) and 12 healthy children (controls). The mean serum zinc levels were significantly lower in cases (79.56 ± 13.40 µg/dl) compared to controls (120.97 ± 20.73 µg/dl; $p<0.001$). Decreased zinc levels were observed in 27.1% of cases, while none of the controls had low zinc levels ($p=0.042$). Among cases, children under 5 years had the lowest mean zinc levels (73.61 ± 12.22 µg/dl), followed by those aged 10–15 years (77.26 ± 15.02 µg/dl) and 5–10 years (83.11 ± 12.76 µg/dl), though differences were not significant. Gender differences in serum zinc levels were also not significant in either group. In cases, malnourished children had slightly higher serum zinc levels (81.14 ± 11.96 µg/dl) than well-nourished children (77.98 ± 14.81 µg/dl; $p=0.421$). In controls, however, malnourished children had significantly lower zinc levels (100.23 ± 8.71 µg/dl) compared to well-nourished children (127.89 ± 18.89 µg/dl; $p=0.038$). Cases with extrapulmonary TB showed higher zinc levels (82.15 ± 11.39 µg/dl) than those with pulmonary TB (78.14 ± 14.37 µg/dl; $p=0.326$). Zinc levels increased significantly with longer ATT duration, ranging from 68.04 ± 10.07 µg/dl (0–1 month) to 93.64 ± 8.82 µg/dl (3–4 months; $p<0.001$). No significant correlation was observed between serum zinc levels and age in either group.

Conclusion: Serum zinc levels were significantly lower in children with tuberculosis compared to healthy controls, with malnutrition contributing to the severity of zinc deficiency. Zinc levels improved with the duration of anti-tubercular therapy, highlighting its potential as a marker for nutritional and treatment recovery.

Keywords: Serum Zinc Levels, Pediatric Tuberculosis, Malnutrition, Antitubercular Therapy, Case control study, India.

Introduction

Tuberculosis (TB) remains a significant global health concern, particularly in low- and middle-income countries. [1] According to the World Health Organization (WHO), TB is one of the leading causes of death from a single infectious agent, surpassing even HIV/AIDS.[2] In 2020, an estimated 10 million people fell ill with TB, and 1.5 million lives were lost to the disease, underscoring its immense global burden. India bears the highest burden of TB worldwide, accounting for 26% of all TB cases globally, which poses a considerable challenge to its public health system.[3] Despite advancements in TB diagnosis, treatment, and prevention, gaps remain in addressing factors that influence treatment outcomes, including nutritional deficiencies. Malnutrition, in particular, is a critical determinant of TB susceptibility, progression, and treatment outcomes. Nutritional deficiencies weaken the immune system, rendering individuals more susceptible to TB infection and impairing their ability to respond effectively to treatment.[4] Among various micronutrients, zinc has emerged as a key element in immune function and host defence mechanisms. Zinc plays a vital role in cell-mediated immunity,[5] an essential component of the immune response against Mycobacterium tuberculosis. Zinc deficiency, which is widespread in many low- and middle-income countries, including India,[6] has been linked to increased susceptibility to infectious diseases, including TB.[7]

The essentiality of zinc in biological systems has been recognized for over a century. Zinc serves as a cofactor for over 300 enzymes involved in a wide range of physiological processes, including DNA and RNA synthesis, cell division, protein metabolism, and immune function. It is a key component of zinc-dependent enzymes and transcription factors, which regulate various cellular and immune processes.[8] The majority of the body's zinc is stored in muscle, bone, and other tissues, with only a small fraction circulating in plasma. Zinc homeostasis is tightly regulated by a balance of dietary intake, absorption, and excretion. Factors such as poor dietary intake, high phytate consumption, and chronic illnesses contribute to zinc deficiency, particularly in resource-limited settings.[9]

Zinc deficiency has profound effects on immune function, particularly cell-mediated immunity, which is crucial for controlling and resolving TB infection. Zinc is essential for the activity of thymulin, a thymus-derived hormone involved in T-cell function, and for maintaining the balance of Th1 and Th2 helper cells.[10] In zinc deficiency, the activity of thymulin is reduced, resulting in impaired T-cell function and increased susceptibility to infections. Additionally, zinc regulates macrophage function, cytokine production, and the activity of natural killer cells, all of which are critical for mounting an effective immune response to TB.[11]

Studies have consistently shown that zinc levels are significantly lower in patients with active TB compared to healthy individuals.[12] This observation has been attributed to various factors, including redistribution of zinc to the liver during infection, increased urinary zinc excretion, and competition for zinc utilization by Mycobacterium tuberculosis.[13] The pathogen's reliance on host zinc for its growth and survival further complicates the host-pathogen interaction. These findings highlight the potential role of zinc supplementation as an adjunctive strategy to improve TB treatment outcomes.[14]

Although previous studies have established the association between zinc deficiency and TB,[15] limited data exist on the impact of zinc supplementation on treatment outcomes, particularly in patients with multidrug-resistant TB (MDR-TB). MDR-TB presents a significant challenge to TB control efforts due to its prolonged treatment duration, higher cost, and lower success rates compared to drug-susceptible TB. Zinc deficiency in MDR-TB patients has been associated with impaired macrophage function, reduced production of cytokines such as tumor necrosis factor-alpha (TNF-α) and interferon-gamma (IFN-γ) and compromised cellular immunity.[16] These immune impairments may delay sputum conversion and hinder treatment success.

Emerging evidence suggests that zinc supplementation may enhance immune function, accelerate sputum conversion, and improve treatment outcomes in TB patients. Studies have shown that zinc supplementation can reduce intestinal permeability, promote mucosal repair, and enhance immune responses in malnourished individuals.[17] Furthermore, zinc has antioxidant properties that protect immune cells from oxidative damage, which is particularly relevant in the inflammatory milieu of TB. Despite these promising findings, the role of zinc supplementation as an adjunctive therapy in TB management remains underexplored, particularly in the context of MDR-TB.[18]

Against this background, the primary objective of the study was to estimate the levels of serum zinc among patients with childhood pulmonary tuberculosis and TB lymphadenitis. The secondary objectives were to determine the correlation between serum zinc levels and patients' nutritional status, clinical type of TB and duration of ATT.

Materials and Methods

This was a hospital-based case control study conducted in the Department of Paediatrics, Vinayaka Missions Medical College and Hospital, Karaikal, over a two-year period from August 2016 to June 2018 after approval by the Institutional Ethical Committee. The recruitment of cases and controls was carried out after obtaining informed written consent in their regional language, ensuring ethical compliance and participant understanding. The study population included 48 children in the case group and 12 children in the control group, all up to the age of 15 years. The case group comprised children with clinical and radiological signs consistent with tuberculosis who were undergoing anti-tuberculosis treatment (ATT). Inclusion criteria for the case group were children up to 15 years of age, clinical and radiological evidence of TB, and laboratory confirmation through tests such as Mantoux and fine needle aspiration cytology (FNAC) from cervical lymph nodes. Exclusion criteria included children with immune deficiencies, other infections, severe illness, chronic diseases, corticosteroid or zinc supplement use in the preceding month, liver diseases (as determined by elevated serum aspartate aminotransferase and alanine aminotransferase levels), cardiovascular diseases, or a history of prior anti-tuberculosis treatment. The control group consisted of healthy children up to 15 years of age who visited the hospital for well-baby check-ups, immunizations, or counselling. These children had no history of TB in the past or present, no illnesses, and had not received ATT at any point.

Data collection was performed using a predesigned proforma aligned with the study objectives. Detailed information was recorded, including relevant medical history, clinical signs and symptoms at presentation, past medical and drug history, and physical examination findings. To measure serum zinc levels, 2 ml of venous blood was collected from each participant under aseptic conditions. Serum zinc levels were estimated using the Nitro PAPS dye method, a colorimetric method performed on the RA-50 semi-auto analyzer. Although atomic absorption spectrometry (AAS) is recognized as the gold standard for zinc estimation, the Nitro PAPS method was used due to its conventional applicability and reliability. The principle of the assay involves the reaction of zinc in an alkaline medium with the water-soluble reagent 2-5-Nitro-2-Pyridylazo-5-N-Propyl-N-sulfopropylami nophenol disodium salt dehydrate (Nitro PAPS) to form a purple-colored complex. The intensity of this complex is directly proportional to the zinc concentration in the serum. The reference range for serum zinc was defined as 70–150 µg/dl.

Statistical analysis: The data were entered into a Microsoft Excel data sheet and analyzed using SPSS software version 22 (IBM SPSS Statistics, Somers, NY, USA). Categorical data were represented as frequencies and proportions, and the chi-square test was employed as the test of significance for qualitative variables. Continuous data were presented as mean and standard deviation (SD). The independent t-test was used as the test of significance to identify the mean difference between two quantitative variables. Graphical representations of the data were created using Microsoft Excel. A p-value of less than 0.05, indicating the probability that the result is true, was considered statistically significant after adhering to all assumptions of the statistical tests.

Results

The study included 48 cases and 12 controls. Among cases, 64.6% had pulmonary TB and 35.4% had lymph node TB (extra pulmonary TB). Among cases, 27.1% were below 5 years of age, 56.2% were between 5 to 10 years, and 16.7% were between 10 to 15 years, while among controls, 33.3% were below 5 years, 41.7% were between 5 to 10 years, and 25% were between 10 to 15 years (p=0.644). Gender distribution was similar in both groups, with females constituting 52.1% of cases and 50% of controls, and males 47.9% of cases and 50% of controls (p=0.897). Malnutrition was present in 50% of cases compared to 25% of controls, though this difference was not statistically significant (p=0.119). The mean serum zinc levels were significantly lower in cases (79.56 ± 13.40 µg/dl) than in controls (120.97 ± 20.73 µg/dl) (p<0.001). Decreased serum zinc levels were observed in 27.1% of cases, while none of the controls had decreased levels, a difference that was statistically significant (p=0.042).

Among cases, children under 5 years had a mean serum zinc level of 73.61 ± 12.22 µg/dl, those aged 5 to 10 years had 83.11 ± 12.76 µg/dl, and those aged 10 to 15 years had 77.26 ± 15.02 µg/dl. In controls, the corresponding values were 126.53 ± 21.91 µg/dl, 115.96 ± 21.28 µg/dl, and 121.93 ± 24.74 µg/dl, with no statistically significant differences between age groups (p=0.094 for cases, p=0.782 for controls).

In terms of gender, female cases had a mean serum zinc level of 78.15 ± 12.64 µg/dl compared to 81.10 ± 14.32 µg/dl in males (p=0.453). In controls, females had a higher mean zinc level (125.53 ± 21.46 µg/dl) than males (116.42 ± 20.86 µg/dl), though the difference was not statistically significant (p=0.473).

For malnutrition, cases with malnutrition had slightly higher mean zinc levels (81.14 ± 11.96 µg/dl) compared to those without malnutrition (77.98 ± 14.81 µg/dl; p=0.421). In contrast, controls with malnutrition had significantly lower serum zinc levels (100.23 ± 8.71 µg/dl) than controls without malnutrition (127.89 ± 18.89 µg/dl; p=0.038).

Among cases, children with pulmonary tuberculosis had a mean serum zinc level of 78.14 ± 14.37 µg/dl, while those with extrapulmonary/lymph node tuberculosis had a slightly higher level of 82.15 ± 11.39 µg/dl (p=0.326). The duration of anti-tuberculosis treatment (ATT) significantly influenced serum zinc levels in cases, with levels increasing progressively from 68.04 ± 10.07 µg/dl in those on treatment for less than 1 month to 93.64 ± 8.82 µg/dl in those treated for 3 to 4 months (p<0.001). In the study, the correlation between serum zinc levels and age was examined for both cases and controls. Among cases, a weak positive correlation was observed (correlation coefficient = 0.160), but it was not statistically significant (p=0.278). In controls, a weak negative correlation was found (correlation coefficient = -0.170), which was also not statistically significant (p=0.597). These findings suggest that there is no significant relationship between serum zinc levels and age in either group.

Table 1: Comparison of study groups, by demographic and clinical characteristics

		Cases N = 48	Controls N = 12	Chi square value
		n (%)	n (%)	P value
Age (in years)	<5 years	13 (27.1)	4 (33.3)	0.879
	5 to 10 years	27 (56.2)	5 (41.7)	0.644
	10-15 years	8 (16.7)	3 (25.0)	
Gender	Female	25 (52.1)	6 (50.0)	0.017
	Male	23 (47.9)	6 (50.0)	0.897
Malnutrition	Present	24 (50.0)	3 (25.0)	2.424
	Absent	24 (50.0)	9 (75.0)	0.119
Serum zinc levels, Mean (SD)		79.56 (13.40)	120.97 (20.73)	<0.001*
Serum zinc levels	Decreased	13 (27.1)	0 (0.0)	4.149
	Normal	35 (72.9)	12 (100)	0.042*
*Statistically significant at p<0.05, SD, Standard deviation				

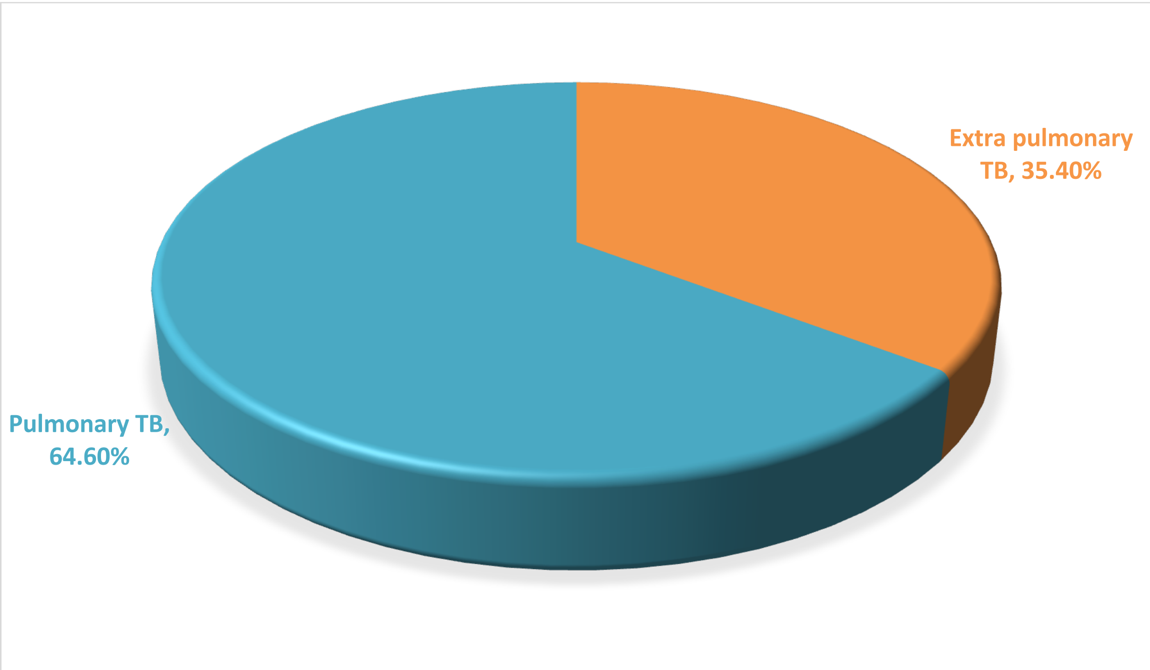

Figure 1: Type of TB cases included in the study

Table 2: Comparison of serum zinc levels varied across different subgroups in both cases and controls

		Serum zinc levels	
		Cases N = 48	Controls N = 12
		Mean (SD)	Mean (SD)
Age (in years)	<5 years	73.61 (12.22)	126.53 (21.91)
	5 to 10 years	83.11 (12.76)	115.96 (21.28)
	10-15 years	77.26 (15.02)	121.93 (24.74)
P value		0.094	0.782
Gender	Female	78.15 (12.64)	125.53 (21.46)
	Male	81.10 (14.32)	116.42 (20.86)
P value		0.453	0.473
Malnutrition	Present	81.14 (11.96)	100.23 (8.71)
	Absent	77.98 (14.81)	127.89 (18.89)
P value		0.421	0.038*
Type of TB	Pulmonary	78.14 (14.37)	_
	Extrapulmonary/Lymph node	82.15 (11.39)	_
P value		0.326	_

ATT duration	0 to 1 month	68.04 (10.07)	_
	1 to 2 months	69.96 (6.16)	_
	2 to 3 months	84.63 (6.93)	_
	3 to 4 months	93.64 (8.82)	_
P value		<0.001*	_
*Statistically significant at p<0.05, SD, Standard deviation			

Table 3: Correlation between serum zinc levels and age among cases and controls

	Cases		Controls	
	Correlation coefficient	**P value**	**Correlation coefficient**	**P value**
Serum zinc levels and age	0.160	0.278	-0.170	0.597

Serum zinc levels and age – cases	**Serum zinc levels and age – controls**

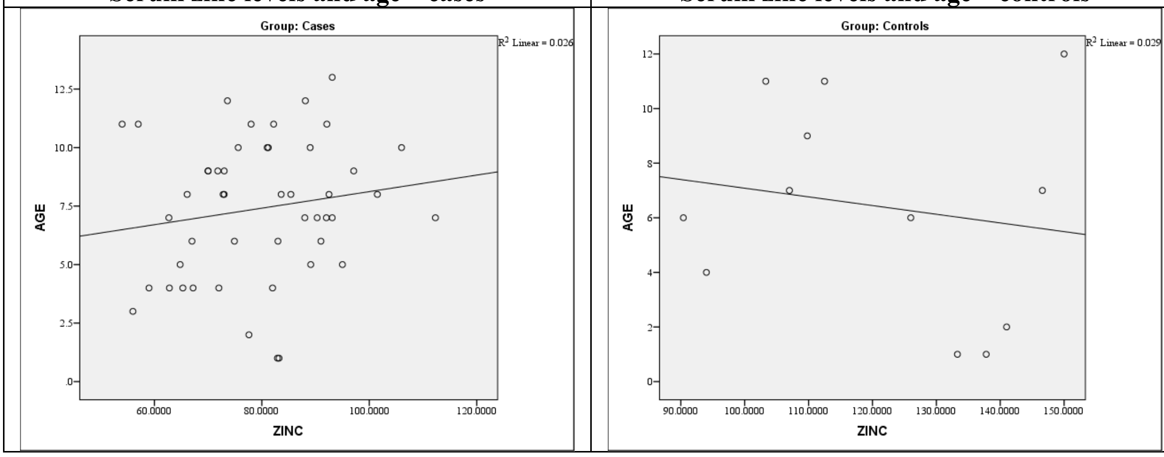

Figure 2: Correlation between serum zinc levels and age among cases and controls

Discussion

The present study explored various factors influencing serum zinc levels in children with tuberculosis, focusing on the relationship between age, sex, nutritional status, type of TB, and the duration of anti-tubercular therapy. The findings in this study contribute to the existing body of literature on the interplay between zinc levels and TB progression in pediatric populations.

The study observed a positive correlation between age and serum zinc levels in children with TB, suggesting that as age increased, zinc levels also tended to rise. However, this correlation did not reach statistical significance, indicating that age may not have a strong influence on zinc concentrations in this specific cohort. This contrasts with the findings of other studies, such as one conducted by Kassu et al.[19] (2006), which reported no significant association between age and serum zinc levels in pulmonary TB patients. Similarly, research by Mohan et al.[20] found no significant relationship between age and zinc levels in TB patients. In contrast, a study by Ghulam et al.[21] (2011) observed an inverse relationship, where zinc levels decreased with age in TB patients. This divergence in results highlights the complexity of the relationship between age and zinc status in TB, suggesting that other factors, such as the severity of the disease or nutritional status, may play more significant roles.

Regarding sex, the study found no significant association between gender and serum zinc levels in children with TB, with a p-value of 0.453. This result aligns with the observations of Khanna et al.[22] (1986), who also found no significant relationship between sex and serum zinc levels in pulmonary TB patients. Additionally, the analysis of sex and zinc levels in the control group revealed no significant difference (p = 0.473), consistent with the findings of Arvanitidou et al.,[23] who also reported no significant relationship between sex and zinc status in children with pulmonary TB. While some studies, such as those by Mashhadi et al.[24] and Dabbaghmanesh et al.,[25] noted slight variations in zinc levels between males and females, these differences were not statistically significant. This suggests that sex may not be a critical determinant of serum zinc levels in both TB patients and healthy controls.

Nutritional status emerged as a significant factor influencing serum zinc levels in the present study. Among the control group, 25% were found to be malnourished, and a significant difference was noted in zinc levels, with malnourished individuals having lower zinc concentrations (p = 0.038). This finding is consistent with other studies, such as those by Ahmed et al.[26] (1991), which reported significantly lower zinc levels in children with protein-energy malnutrition compared to healthy controls. Zinc deficiency is commonly observed in malnourished children, especially in developing countries where diets are often insufficient in zinc-rich foods. The inadequate intake of foods containing zinc, coupled with factors like poor absorption due to high phytate levels in grains and legumes, further exacerbates zinc deficiency. Additionally, malnutrition leads to decreased thymulin activity and impaired immune function, particularly in relation to T-cell proliferation and neutrophil chemotaxis.[27] This could predispose children to infections like TB, where immune system deficiencies play a crucial role in disease progression.

The study also assessed the relationship between nutritional status and serum zinc levels in different forms of TB, specifically pulmonary TB and TB lymphadenitis. Among children with TB, 50% were malnourished, but no significant difference in zinc levels was observed between those with normal nutrition and those with undernutrition ($p = 0.421$). Similar findings were reported by Ray et al.[17] (2009), who found no statistically significant difference in zinc levels between malnourished and well-nourished children with TB. This suggests that while malnutrition may contribute to lower zinc levels, its impact on zinc status may not be as pronounced in the context of active TB, possibly due to the complex interplay between infection, inflammation, and nutritional factors.

When examining the type of TB, the study found that children with pulmonary TB had slightly lower serum zinc levels (78.14 μg/dl) compared to those with TB lymphadenitis (82.15 μg/dl), but this difference was not statistically significant. This finding contrasts with previous research by Ray et al.[17] (2009), who found lower zinc levels in children with pulmonary TB compared to TB lymphadenitis. However, Mittal et al.[28] (2015) reported that children with pulmonary TB had similar or slightly lower zinc levels compared to those with TB lymphadenitis. The variability in results could be due to differences in study populations, disease severity, or the methods used to measure zinc concentrations.

The study also investigated the effect of ATT duration on serum zinc levels. The results showed a significant increase in zinc levels as the duration of ATT progressed. Specifically, mean zinc levels rose from 68.04 μg/dl in the 0-1 month period to 93.64 μg/dl in the 3-4 month period. This suggests that the initiation of ATT may contribute to the normalization of zinc levels, which is consistent with findings from other studies, such as those by Mohan et al.[18] (2007) and Halsted et al.[29] (1972), who observed that zinc levels were significantly lower in TB patients at the start of treatment but improved with continued therapy. The improvement in zinc status with ATT could reflect a reduction in the disease burden, leading to less systemic inflammation, which is known to impair zinc absorption and utilization. Additionally, the restoration of nutritional intake and the healing process may support zinc absorption and better overall immune function.

Conclusion

In conclusion, the present study highlighted a significant decrease in serum zinc levels in children with tuberculosis when compared to healthy controls, emphasizing the impact of the disease on zinc status. The study further revealed that malnutrition was strongly associated with lower zinc levels, suggesting that nutritional deficiencies play a critical role in the severity of zinc deficiency in children with TB. While children with pulmonary tuberculosis had lower mean zinc levels compared to those with TB lymphadenitis, the difference was not statistically significant, indicating that the type of TB may not have a strong influence on zinc status. However, a significant correlation was observed between the duration of anti-tubercular therapy and serum zinc levels, with higher zinc levels seen as the duration of treatment increased. This finding underscores the potential of serum zinc as a useful marker for monitoring the nutritional status and overall recovery of children undergoing anti-tubercular therapy. Consequently, regular monitoring of zinc levels in TB patients, particularly during treatment, could provide valuable insights into their nutritional and immune recovery, guiding more effective therapeutic interventions.

References

1. Bai W, Ameyaw EK. Global, regional and national trends in tuberculosis incidence and main risk factors: a study using data from 2000 to 2021. BMC Public Health. 2024; 24(1):12.
2. Trajman A, Felker I, Alves LC, Coutinho I, Osman M, Meehan SA, et al. The COVID-19 and TB syndemic: the way forward. Int J Tuberc Lung Dis. 2022; 26(8):710-9.
3. Mandal S, Rao R, Joshi R. Estimating the Burden of Tuberculosis in India: A Modelling Study. Indian J Community Med. 2023; 48(3):436-42.
4. Chandrasekaran P, Saravanan N, Bethunaickan R, Tripathy S. Malnutrition: Modulator of Immune Responses in Tuberculosis. Front Immunol. 2017; 8:1316.
5. Wessels I, Maywald M, Rink L. Zinc as a Gatekeeper of Immune Function. Nutrients. 2017; 9(12).
6. Gupta S, Brazier AKM, Lowe NM. Zinc deficiency in low- and middle-income countries:

prevalence and approaches for mitigation. J Hum Nutr Diet. 2020; 33(5):624-43.
7. Zolfaghari B, Ghanbari M, Musavi H, Bavandpour Baghshahi P, Taghikhani M, Pourfallah F. Investigation of Zinc Supplement Impact on the Serum Biochemical Parameters in Pulmonary Tuberculosis: A Double Blinded Placebo Control Trial. Rep Biochem Mol Biol. 2021; 10(2):173-82.
8. Costa MI, Sarmento-Ribeiro AB, Gonçalves AC. Zinc: From Biological Functions to Therapeutic Potential. Int J Mol Sci. 2023; 24(5).
9. Maares M, Haase H. A Guide to Human Zinc Absorption: General Overview and Recent Advances of In Vitro Intestinal Models. Nutrients. 2020; 12(3).
10. Shankar AH, Prasad AS. Zinc and immune function: the biological basis of altered resistance to infection. Am J Clin Nutr. 1998; 68(2 Suppl):447s-63s.
11. Gammoh NZ, Rink L. Zinc in Infection and Inflammation. Nutrients. 2017; 9(6).
12. Keflie TS, Samuel A, Woldegiorgis AZ, Mihret A, Abebe M, Biesalski HK. Vitamin A and zinc deficiencies among tuberculosis patients in Ethiopia. J Clin Tuberc Other Mycobact Dis. 2018; 12:27-33.
13. Karyadi E, Schultink W, Nelwan RH, Gross R, Amin Z, Dolmans WM, et al. Poor micronutrient status of active pulmonary tuberculosis patients in Indonesia. J Nutr. 2000;130(12):2953-8.
14. Visser ME, Grewal HM, Swart EC, Dhansay MA, Walzl G, Swanevelder S, et al. The effect of vitamin A and zinc supplementation on treatment outcomes in pulmonary tuberculosis: a randomized controlled trial. Am J Clin Nutr. 2011; 93(1):93-100.
15. Barman N, Haque Khan MM, Ghosh D, Ibne Towhid MI, Uddin MN, Paul D, et al. Serum Zinc Level and Its Association with Multidrug-Resistant Tuberculosis. The International Journal of Mycobacteriology. 2021; 10(2).
16. Lee JS, Song CH, Lim JH, Kim HJ, Park JK, Paik TH, et al. The production of tumour necrosis factor-alpha is decreased in peripheral blood mononuclear cells from multidrug-resistant tuberculosis patients following stimulation with the 30-kDa antigen of Mycobacterium tuberculosis. Clin Exp Immunol. 2003; 132(3):443-9.
17. Ray M, Kumar L, Prasad R. Plasma zinc status in Indian childhood tuberculosis: impact of antituberculosis therapy. Int J Tuberc Lung Dis. 1998; 2(9):719-25.
18. Mohan G, Kulshreshtha S, Dayal R, Singh M, Sharma P. Effect of therapy on serum zinc and copper in primary complex of children. Biol Trace Elem Res. 2007; 118(2):184-90.
19. Kassu A, Yabutani T, Mahmud ZH, Mohammad A, Nguyen N, Huong BT, et al. Alterations in serum levels of trace elements in tuberculosis and HIV infections. Eur J Clin Nutr. 2006; 60(5):580-6.
20. Mohan G, Kulshreshtha S, Sharma P. Zinc and copper in Indian patients of tuberculosis: impact on antitubercular therapy. Biol Trace Elem Res. 2006; 111(1-3):63-9.
21. Ghulam H, Kadri SM, Manzoor A, Waseem Q, Aatif MS, Khan GQ, et al. Status of zinc in pulmonary tuberculosis. J Infect Dev Ctries. 2009; 3(5):365-8.
22. Khanna B, Kumar R, Mukerji P, Chowdhury A, Kamboj V. Plasma copper and zinc levels in pulmonary tuberculosis. 1982.
23. Arvanitidou V, Voskaki I, Tripsianis G, Athanasopoulou H, Tsalkidis A, Filippidis S, et al. Serum copper and zinc concentrations in healthy children aged 3–14 years in Greece. Biological trace element research. 2007; 115:1-12.
24. Mashhadi M, Bakhshipour A, Zakeri Z, Ansari-Moghaddam A. Reference Range for Zinc Level in Young Healthy Population in Southeast of Iran. Health Scope. 2016; In Press.
25. Dabbaghmanesh MH, Taheri Boshrooyeh H, Kalantarhormozi MR, Ranjbar Omrani GH. Assessment of zinc concentration in random samples of the adult population in Shiraz, iran. Iran Red Crescent Med J. 2011; 13(4):249-55.
26. Ahmed TM, Mahmood Mt. Serum Zinc Level in Children with Malnutrition. Journal of Pediatric Gastroenterology and Nutrition. 1998; 27(2):257.
27. Lönnerdal B. Dietary factors influencing zinc absorption. J Nutr. 2000; 130(5S Suppl): 1378s-83s.
28. Mittal P, Kalra P. Serum zinc levels in children 6 months–12 years having tuberculosis. Pediatric Infectious Disease. 2015; 7(2):36-40.
29. Halsted J, Smith JC. Plasma-Zinc in Health and Disease. The Lancet. 1970; 295(7642): 322-4.