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Association between serum zinc concentrations and body mass index in patients with pulmonary tuberculosis: A case–control study

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Abstract

Introduction: Pulmonary tuberculosis (PTB) is often linked to poor nutritional status, including zinc deficiency. Since both zinc and body mass index (BMI) influence immune function, this study investigates the association between BMI and serum zinc levels in PTB patients compared to healthy controls.

Methods: This analytical case–control study was carried out in the Department of Internal Medicine at Bangladesh Medical University, Dhaka, Bangladesh, spanning from January 1, 2015, to January 31, 2016. A total of 91 participants were recruited, comprising 43 newly diagnosed PTB patients as cases and 48 tuberculosis-negative individuals as controls. The cases included both inpatients and outpatients who had not yet commenced anti-tubercular treatment at the time of enrolment.

Results: In this study involving 91 participants, PTB patients had significantly lower BMI than controls ($P = 0.014$), but no significant association was found between BMI and serum zinc levels in either group. Although mean serum zinc levels appeared to rise with increasing BMI, the differences were not statistically significant across BMI categories ($P = 0.642$), suggesting that BMI alone may not predict zinc status in PTB patients.

Conclusion: This study demonstrated that although patients with PTB had significantly lower BMI compared to healthy controls, serum zinc concentrations did not show a statistically significant association with BMI in either group. Despite a trend toward higher zinc levels with increasing BMI, particularly among controls, the differences were not meaningful.

Keywords: Body mass index, pulmonary tuberculosis, serum zinc concentrations

Introduction

Tuberculosis (TB) continues to be one of the leading causes of morbidity and mortality from infectious diseases globally. In 2023, the World Health Organization reported approximately 10.6 million new TB cases and 1.3 million TB-related deaths worldwide.[1] Countries with a high burden of TB, such as Bangladesh, continue to face challenges in controlling the disease due to factors, such as poverty, undernutrition, and inadequate healthcare access.[2] Malnutrition plays a dual role in TB pathogenesis: It acts as both a risk factor for acquiring TB and a consequence of active infection. Undernourished individuals are more likely to develop TB due to impaired cell-mediated immunity, while active TB further worsens nutritional status by increasing metabolic demand and reducing appetite.[3] Body mass index (BMI), a simple anthropometric marker of nutritional status, is commonly used to evaluate undernutrition in TB patients. Several studies have shown that low BMI is associated with increased TB risk, delayed recovery, and higher mortality.[4] Micronutrient deficiencies, particularly of zinc, are common among TB patients and are known to further impair immune responses. Zinc is an essential trace element required for numerous biological functions, especially immune regulation. It supports the activity of macrophages, natural killer cells, and T-lymphocytes, all of which are critical for the host's defense against *Mycobacterium tuberculosis*.[5] Zinc deficiency can suppress these immune mechanisms, leading to increased susceptibility to infections, including TB.[6] Moreover, zinc possesses antioxidant properties, helps regulate inflammatory responses, and maintains epithelial barrier integrity, all of which are crucial in respiratory infections, such as TB.[7] A growing body of evidence indicates that patients with active pulmonary TB (PTB) often exhibit significantly lower serum zinc concentrations compared to healthy individuals, and this deficiency is frequently associated with disease severity.[8,9] One study in Bangladesh reported significantly reduced serum zinc levels in PTB patients compared to controls, suggesting a correlation between zinc deficiency and disease progression.[10] On the other hand, BMI may influence the availability and metabolism of micronutrients, including zinc. Malnourished individuals with low BMI may have impaired zinc absorption and increased losses due to chronic inflammation or catabolic stress.[11] Some studies suggest that zinc concentrations may vary with nutritional status, though findings remain inconsistent.[8] It is therefore important to assess whether there is a significant association between serum zinc levels and BMI, particularly in patients with TB who are at risk of both deficiencies. Despite recognition of the individual roles of zinc and BMI in TB, limited studies have examined their interrelationship. In resource-limited settings, such as Bangladesh, where both TB and malnutrition are endemic, such an association has practical significance. Evaluating the link between serum zinc concentration and BMI in TB patients could offer insight into the nutritional-immune axis and inform targeted nutritional interventions. This, in turn, may enhance immune response, improve treatment outcomes, and support the development of comprehensive TB management strategies. Therefore, the present study aims to assess the association between serum zinc concentrations and BMI in patients with PTB and compare these parameters with TB-negative controls.

Methods

This analytical case–control study was carried out in the Department of Internal Medicine at Bangladesh Medical University (BMU), Dhaka, Bangladesh, spanning from January 1, 2015, to January 31, 2016. A total of 91 participants were recruited, comprising 43 newly diagnosed PTB patients as cases and 48 TB-negative individuals as controls. The cases included both inpatients and outpatients who had not yet commenced anti-tubercular treatment at the time of enrolment. Controls were selected from individuals attending the outpatient department who exhibited no abnormalities in routine investigations, had non-TB illnesses, or were healthy attendants willing to undergo screening. Participants were chosen using a convenience sampling technique, without restrictions on gender, ethnicity, or residential status, provided they were between 18 and 60 years of age. Subjects with co-morbidities were excluded, as were those with extra-PTB, a history of prior anti-TB therapy, diabetes mellitus, chronic liver disease, renal dysfunction, myocardial infarction, malignancy, nephritis, pregnancy, oral contraceptive use, or those taking zinc supplementation. Data collection involved direct interviews using a pre-structured questionnaire, detailed clinical examination, and relevant investigations. PTB diagnosis was based on clinical symptoms, such as persistent cough (≥3 weeks), fever, and weight loss, and was confirmed microbiologically through either sputum smear microscopy for acid-fast bacilli or by using GeneXpert (Xpert *Mycobacterium* TB/resistance to rifampin assay). A participant was categorized as a PTB case if either test yielded a positive result. In contrast, TB was excluded in the control group based on clinical evaluation, laboratory tests, or self-reported health status. Potential co-morbid conditions were ruled out through history, clinical examination, and investigations. After obtaining written informed consent, venous blood samples were collected for serum zinc analysis. Serum zinc concentration was measured using atomic absorption spectrophotometry. All results were documented in the data sheet. Ethical clearance for the study was granted by the Institutional Review Board of BSMMU. Data were entered and analyzed using the Statistical Package for the Social Sciences version 21. Descriptive statistics, including mean and standard deviation, were used for continuous variables. Independent samples *t*-test and analysis of variance, were applied for comparing quantitative variables between groups, while the Chi-square test assessed associations between categorical variables. A $P < 0.05$ was considered statistically significant.

Results

The average age of participants was comparable between PTB cases (33.3 years) and controls (32.7 years), with no significant difference ($P = 0.859$). Although more females were found in the control group and more males in the case group, gender distribution was not statistically significant. A higher percentage of smokers was observed among cases (30.2%) compared to controls (16.7%), though not significant ($P = 0.125$). Mean BMI was significantly lower in the PTB group ($P = 0.014$). Bacille Calmette-Guérin (BCG) vaccination scars were present in the majority of both groups [Table 1].

Among PTB patients, the majority presented with prolonged cough (95.4%), fever (88.4%), and weight loss (83.7%). A history of close TB contact was more common in cases (11.6%) than in controls (4.7%). On clinical examination, 16.3% of PTB cases had documented fever, and 18.6% exhibited signs of pulmonary consolidation [Table 2].

The mean serum zinc concentrations showed a progressive rise with increasing BMI in both case and control groups. In the case group, serum zinc levels increased slightly from the low BMI group to the normal BMI group, but the difference was not statistically significant ($P = 0.879$). Among the controls, although those with higher BMI showed relatively higher serum zinc concentrations, none

Table 1: Demographic characteristics of the study subjects (*n*=91)

Parameter	Case (*n*=43) (%)	Control (*n*=48) (%)	*P*-value
Age (years)	33.30±14.71	32.69±11.60	0.859
18–29 years	19 (44.2)	23 (47.9)	
30–44 years	12 (27.9)	14 (29.2)	
45–60 years	12 (27.9)	11 (22.9)	
Gender			0.268
Male	22 (51.2)	19 (39.6)	
Female	21 (48.8)	29 (60.4)	
Smoking	13 (30.2)	08 (16.7)	0.125
BMI (kg/m²)	19.88±2.31	22.08±2.80	0.014*
Low (<18.5)	07 (16.3)	05 (12.5)	
Normal (18.5–24.9)	36 (83.7)	34 (70.8)	
High (>24.9)	–	08 (16.7)	
BCG scar present	29 (67.4)	38 (79.2)	0.205

BCG: Bacille Calmette-Guérin, BMI: Body mass index.
*Statistically significant difference in BMI (*P*=0.014) between cases and controls

Table 2: Clinical presentation and examination findings of the study subjects (*n*=91)

Parameter	Case (*n*=43) (%)	Control (*n*=48) (%)
History of fever	38 (88.4)	–
Cough≥3 weeks	41 (95.4)	08 (16.7)
Weight loss	36 (83.7)	–
Close TB contact	05 (11.6)	02 (4.7)
Fever on examination	07 (16.3)	–
Pulmonary consolidation	08 (18.6)	–

TB: Tuberculosis

of the pairwise comparisons among BMI categories reached statistical significance (all $P > 0.05$). Overall, no significant association was found between BMI and serum zinc concentrations ($P = 0.642$) [Table 3-5].

The scatter diagram shows positive correlation of serum zinc of moderate strength with increasing BMI [Figure 1].

Discussion

The present study investigated the association between serum zinc concentrations and BMI in patients with PTB compared to healthy controls. Our results revealed a significantly lower BMI in PTB patients than in controls ($P = 0.014$), which aligns with the well-documented relationship between TB and undernutrition. However, although serum zinc concentrations tended to increase with higher BMI in both groups, this association did not reach statistical significance. TB has long been associated with nutritional deficiencies, particularly micronutrients, such as zinc. Zinc is vital for immune competence, particularly in combating intracellular pathogens, such as *M. tuberculosis*. Several studies have established that zinc levels are often reduced in individuals with active TB. For instance, Pakasi *et al*. demonstrated significantly reduced plasma zinc levels among TB patients compared to controls, suggesting zinc's potential role in TB pathogenesis and recovery.[12] Similarly, Mythili and Lalitha found lower serum zinc levels in PTB patients, which improved after anti-tubercular treatment.[13] Our study supports the notion of hypozincemia in PTB, although the difference between cases and controls was not statistically significant when stratified by BMI. This trend corresponds with previous findings by Sepehri *et al*., who reported that both zinc deficiency and lower BMI were common among TB patients, but the correlation between BMI and serum zinc was modest.[14] In contrast, Aslam

Table 3: Mean serum zinc concentrations (µg m/L) according to BMI in cases and controls (n=91)

BMI category	Case (n=43) mean±SD	Control (n=48) mean±SD	P-value*
Low (<18.5)	828.57±203.18	948.33±302.82	
Normal (18.5–24.9)	843.33±237.44	961.47±221.58	
High (>24.9)	–	996.25±162.56	0.642

BMI: Body mass index. *Chi-square test of independence used to assess the association between BMI and serum zinc

Table 4: Independent samples t-test: Comparison between low and normal BMI in the case group

Comparison	t-value	P-value*
Low versus normal BMI	−0.154	0.879

BMI: Body mass index. *t-test used to compare serum zinc between BMI groups in cases

Table 5: ANOVA with Bonferroni *post hoc*: Multiple comparisons among the control group by BMI

Comparison	Mean difference	SE	P-value**	95% CI (lower-upper)
Normal versus low	13.14	99.32	1.000	−233.84–260.11
Normal versus high	−34.78	88.13	1.000	−253.95–184.39
Low versus high	−47.92	121.13	1.000	−349.14–253.30

ANOVA: Analysis of variance, BMI: Body mass index, CI: Confidence interval. **One-way ANOVA with Bonferroni *post hoc* test used for between-group comparisons in controls

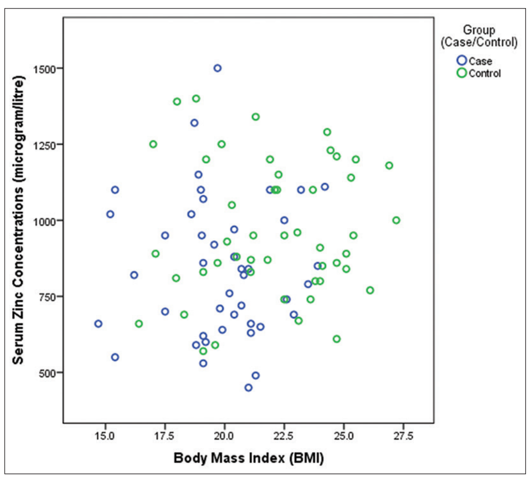

Figure 1: Scatter diagram showing distribution of serum zinc concentrations in relation to body mass index

et al. identified a more significant association between zinc status and BMI in PTB, suggesting that malnourished patients had substantially lower zinc concentrations.[15] The relationship between BMI and serum zinc is complex. Low BMI can be both a cause and consequence of TB, often linked with reduced dietary intake, malabsorption, and increased catabolism, which also depletes trace elements, such as zinc. As zinc plays a critical role in T-cell-mediated immunity, its deficiency may predispose individuals to TB infection and progression. However, the lack of a statistically significant association in our data between BMI subgroups and serum zinc suggests that factors beyond body mass – such as inflammatory status, dietary intake, and gastrointestinal absorption – may influence zinc levels more directly. Our observation that the highest zinc concentrations were found among controls with high BMI is supported by other studies indicating a positive correlation between BMI and serum zinc in the general population. For instance, Rahman *et al*. observed that individuals with higher BMI had higher serum zinc, possibly due to better nutritional intake.[16] Conversely, in chronic infections, such as TB, zinc metabolism is altered due to redistribution of zinc to the liver and increased urinary excretion.[17] BCG vaccination status and smoking history, which were recorded in our study, were not significantly associated with BMI or serum zinc levels. Although BCG scar prevalence was slightly lower among cases, this difference was not statistically significant. Prior studies have shown variable impact of BCG on TB susceptibility but no direct influence on serum zinc.[18] Furthermore, while most of our TB patients reported classical symptoms, such as prolonged cough, fever, and weight loss – consistent with findings from Ritz *et al*. – these clinical presentations were not independently associated with serum zinc levels.[19] This suggests that clinical severity may not be linearly related to zinc deficiency. Despite a trend toward higher zinc with increasing BMI, the lack of statistical significance in our study might be attributed to a relatively small sample size and wide inter-individual variability. Similar limitations were noted in the work of Gebremicael *et al*., who emphasized the need for longitudinal studies to establish a causal link between zinc status and TB outcomes.[20]

Limitations of the study

The study was conducted in a single hospital with a small sample size. Hence, the results may not represent the whole community.

Conclusion

This study demonstrated that although patients with PTB had significantly lower BMI compared to healthy controls, serum zinc concentrations did not show a statistically significant association with BMI in either group. Despite a trend toward higher zinc levels with increasing BMI, particularly among controls, the differences were not meaningful. These findings suggest that while nutritional status as reflected by BMI may differ in PTB, serum zinc concentration is not directly influenced by BMI alone.

Recommendation

Routine nutritional assessment, including BMI and micronutrient evaluation, such as serum zinc, should be considered in patients with PTB to guide supportive care. However, as this study did not find a significant association between BMI and serum zinc levels, future research should explore other contributing factors affecting zinc status in TB patients, including dietary intake, inflammation, and absorption, to develop more targeted nutritional interventions.

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Conflict of Interest

None declared.

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