



Original Research Article

ASSOCIATION OF SERUM ZINC LEVELS AND CLINICO-DEMOGRAPHIC PREDICTORS WITH ACUTE LOWER RESPIRATORY TRACT INFECTIONS IN CHILDREN

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ABSTRACT

Background: The aim is to evaluate serum zinc levels in children hospitalized with acute lower respiratory tract infections (ALRTIs) and determine their association with various clinico-demographic, nutritional, and environmental variables.

Materials and Methods: This prospective, observational, case-control study was conducted over a 16-month period (July 2023 – December 2024) at the Department of Paediatrics, Gayatri Vidya Parishad Institute of Health Care and Medical Technology, Visakhapatnam. The study enrolled 30 children aged 6 months to 5 years clinically diagnosed with ALRTI (cases) and 30 age-matched healthy children (controls). Children with prior antibiotic use, chronic liver or malabsorption diseases affecting zinc metabolism, and severe diarrhoea within two weeks of admission were excluded.

Results: At presentation, fever and tachypnoea were present in all cases (100%), followed by cough (90%), crackles (90%), wheezing (80%), and chest indrawing (76.7%). Cases demonstrated significantly lower mean serum zinc levels compared to controls 62.34 ± 28.16 ($\mu\text{g/dl}$) vs. 81.68 ± 27.65 ($\mu\text{g/dl}$), with a p-value of 0.001. Anthropometric parameters—including weight-for-age (W/A%), height-for-age (H/A%), and weight-for-height (W/H%) percentages—were significantly lower in the case group ($p = 0.007$ for overall nutritional status), indicating a strong link to malnutrition. Biochemical analysis revealed significantly lower albumin levels and elevated C-reactive protein (CRP) levels among cases compared to controls, reflecting active inflammatory responses and underlying nutritional deficiencies.

Conclusion: Low serum zinc levels, poor nutritional status, and elevated inflammatory markers (CRP) are strongly associated with the incidence and severity of ALRTIs in young children. Environmental risk factors, such as biomass fuel exposure and parental smoking, further compound this risk. These findings suggest that addressing childhood malnutrition and implementing targeted zinc supplementation could significantly improve paediatric respiratory health outcomes in resource-limited settings.

Keywords: Acute lower respiratory tract infections (ALRTI); Zinc deficiency; Paediatrics; Nutritional status; Case-control study; C-reactive protein (CRP).

INTRODUCTION

Acute lower respiratory tract infections (ALRTIs), including severe conditions such as pneumonia and bronchiolitis, remain a leading cause of morbidity

and mortality among children under five years of age in low- and middle-income nations. According to the World Health Organization (WHO), pneumonia alone accounts for approximately 18% of all paediatric deaths globally, making it a primary driver

of paediatric hospitalizations and mortality.^[1] In young children, this micronutrient-driven immunodeficiency significantly elevates susceptibility to infections, particularly ALRTIs.^[2] For instance, a case-control study in Nigeria demonstrated that children with ALRTIs had significantly lower mean serum zinc levels ($18.7 \pm 11.8 \mu\text{g/dl}$) than their healthy counterparts ($53.1 \pm 18.5 \mu\text{g/dl}$), with zinc deficiency present in 98.3% of the infected cohort compared to 64.2% of the control group.^[2] Similarly, an Indian study observed reduced serum zinc concentrations ($59.52 \pm 1.55 \mu\text{g/dl}$), among children presenting with severe pneumonia and mild-to-moderate malnutrition. Conversely, children with adequate nutritional status maintained normal zinc ranges, indicating that protein-energy malnutrition may compound zinc deficiency and further compromise immune defences.^[3] Given these links, the therapeutic and prophylactic benefits of zinc supplementation have been widely investigated. In a randomized controlled trial involving 609 children aged 6 to 35 months, daily supplementation with 10 mg of elemental zinc led to a 45% reduction in ALRTI incidence, concurrently reducing the proportion of children with plasma zinc concentrations below.^[4] However, evidence regarding zinc as an adjunct therapy during acute pneumonia remains mixed. While some trials report no significant reduction in illness duration or symptom severity, others indicate a reduction in mortality rates, particularly in high-risk sub-populations, such as children with HIV.^[5] Socioeconomic disparities in Andhra Pradesh drive zinc deficiencies that compromise paediatric immunity, exacerbating childhood malnutrition and respiratory illnesses. Investigating local serum zinc levels enables targeted nutritional interventions that can mitigate the ALRTI burden and reduce under-five mortality.

MATERIALS AND METHODS

Study Design and Setting: This prospective, observational, case-control study was conducted in the Department of Paediatrics at the Gayatri Vidya Parishad Institute of Health Care and Medical Technology, Marikavalasa, Visakhapatnam, Andhra Pradesh, India. The study was carried out over a 16-month period from July 2023 to December 2024.

Selection Criteria

Inclusion Criteria:

Subjects were eligible for enrolment if they met the following criteria:

- Children aged between 6 months and 5 years.
- Presenting with a definitive clinical diagnosis of an acute lower respiratory tract infection (ALRTI), such as pneumonia, bronchitis, or bronchiolitis, requiring hospital admission.
- Provision of written informed consent by the parents or legal guardians for participation, including voluntary blood sampling.

Exclusion Criteria:

Children meeting any of the following parameters were excluded:

- History of antibiotic administration prior to hospital admission for the current illness.
- Diagnosed chronic systemic illnesses known to alter zinc metabolism, such as chronic liver disease or malabsorption syndromes.
- History of severe diarrhoea or significant gastrointestinal illness within the two weeks prior to admission.

Data Analysis: Data was managed in Microsoft Excel and analyzed using SPSS version 23, utilizing descriptive statistics to present sociodemographic and clinical characteristics. Independent t-tests and ANOVA assessed differences in mean serum zinc levels across subgroups, while linear regression evaluated its relationship with clinical outcomes; significance was set at $p < 0.05$.

RESULTS

Table 1: Age Characteristics of the Study Population

Age group, months	Cases (N = 30)	Controls (N = 30)	P Value
<12 months	10 (33.3%)	11 (36.7%)	0.955
12-36 months	12 (40%)	11 (36.7%)	
26-59 months	8 (26.7%)	8 (26.7%)	
Total	30 (100%)	30 (100%)	

Statistical analysis revealed no significant difference in distribution across age groups between cases and controls, as indicated by a p-value of 0.955.

Table 2: Sex distribution

Sex distribution	Cases (N = 30)	Controls (N = 30)	P Value
Male	17 (56.7%)	18 (60%)	0.793
Female	13 (43.3%)	12 (40%)	
Total	30 (100%)	30 (100%)	

The proportions of males and females were comparable between cases and controls, with no statistically significant difference observed (p-value = 0.793).

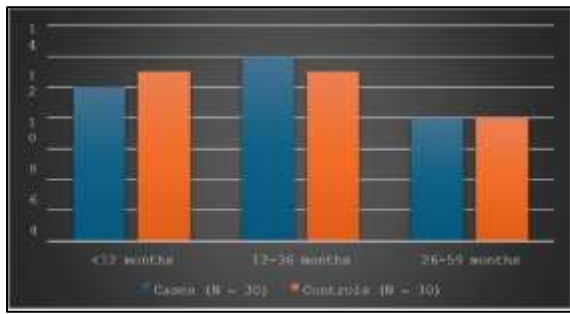


Figure 1: Age Characteristics of the Study Population

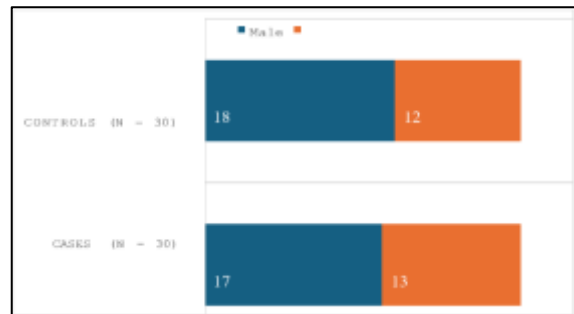


Figure 2: Sex distribution

Table 3: Nutritional status

Weight-for-height %	Cases (N = 30)	Controls (N = 30)	P Value
<90	14 (46.7%)	8 (26.7%)	0.007
≥90	16 (53.3%)	22 (73.3%)	
Total	30 (100%)	30 (100%)	

Table compares nutritional status between cases and controls (N = 30 each). Among cases, 46.7% had a nutritional status <90, compared to 26.7% of

controls. Conversely, 53.3% of cases and 73.3% of controls had a nutritional status ≥90. The difference is statistically significant (p = 0.007).

Table 4: Characteristics

Characteristic		Cases (N = 30)	Controls (N = 30)	P Value
Parental smoking	Yes	5 (16.7%)	6 (20%)	0.05
	No	25 (83.3%)	24 (80%)	
Use of biomass fuels	Yes	4 (13.3%)	2 (6.7%)	0.05
	No	26 (86.7%)	28 (93.3%)	

In examining environmental characteristics, 16.7% of cases (5 individuals) and 20% of controls (6 individuals) had parents who smoked, while 83.3% of cases (25 individuals) and 80% of controls (24 individuals) did not report parental smoking, with a borderline p- value of 0.05. Regarding the use of

biomass fuels, 13.3% of cases (4 individuals) were exposed compared to 6.7% of controls (2 individuals), while the majority in both groups were not exposed (86.7% of cases and 93.3% of controls). This also yielded a significant p-value of 0.05.

Table 5: Sociodemographic Profile: Father's Education Level in ARI and Control Groups

Education Level of Father	Cases (N = 30)	Controls (N = 30)	P Value
No formal education	6 (20%)	2 (6.7%)	0.319
Primary	9 (30%)	7 (23.3%)	
Secondary	7 (23.3%)	8 (26.7%)	
Post-secondary (college)	8 (26.7%)	13 (43.3%)	
Total	30 (100%)	30 (100%)	

Differences in paternal education level between cases and controls were not statistically significant (p-value = 0.319).

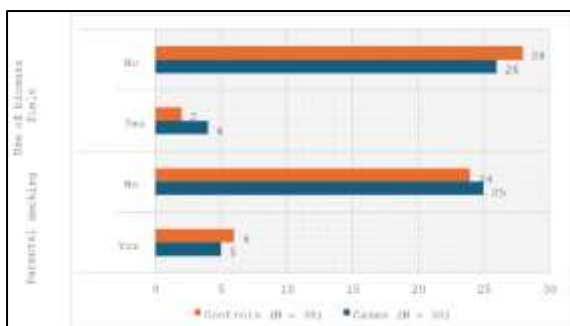


Figure 4: Characteristic

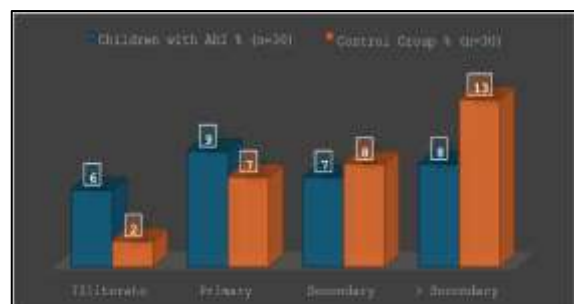


Figure 5: Sociodemographic Profile: Father's Education Level in ARI and Control Groups

Table 6: Maternal education

Maternal education	Cases (N = 30)	Controls (N = 30)	P Value
No formal education	6 (20%)	5 (16.7%)	0.700
Primary	10 (33.3%)	7 (23.3%)	
Secondary	8 (26.7%)	12 (40%)	

Post-secondary (college)	6 (20%)	6 (20%)	
Total	30 (100%)	30 (100%)	

The differences in maternal education between cases and controls were not statistically significant (p-value = 0.700).

Table 7: Socioeconomic status

Socioeconomic status	Cases (N = 30)	Controls (N = 30)	P Value
I	3 (10%)	4 (13.3%)	0.718
II	4 (13%)	7 (23.3%)	
III	7 (23.3%)	8 (26.7%)	
IV	9 (30%)	7 (23.3%)	
V	7 (23.3%)	4 (13.3%)	
Total	30 (100%)	30 (100%)	

This study's participants' socioeconomic distribution was evaluated using the modified Kuppaswamy scale. A p-value of 0.718 indicates that there was no discernible difference in the two groups' socioeconomic classifications according to statistical analysis.

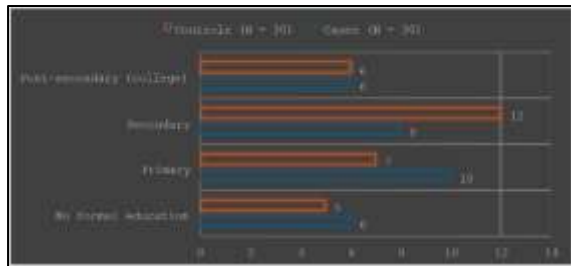


Figure 6: Maternal education

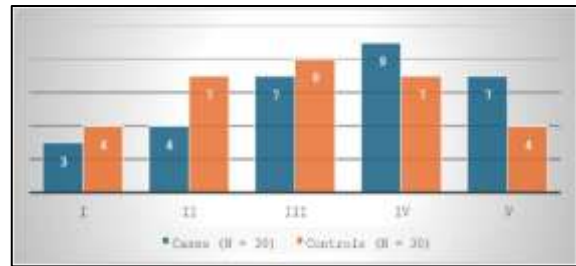


Figure 7: Socioeconomic status

Table 8: Clinical Profile of Children with Acute lower respiratory tract infection

Clinical Characteristic	Frequency (%)
Fever	30 (100%)
Cough	27 (90%)
Refusal to feed	17 (56.7%)
Lethargy	8 (26.7%)
Sleep disturbance	11 (36.7%)
Altered sensorium	3 (10%)
Tachypnea	30 (100%)
Hypoxia (SpO ₂ < 93% in room air)	13 (43.3%)
Cyanosis	4 (13.3%)
Chest indrawing	23 (76.7%)
Stridor/grunting	8 (26.7%)
Reduced air entry	8 (26.7%)
Wheeze	24 (80%)
Crackles	27 (90%)

According to the clinical features seen in the instances, fever and tachypnea were present in every patient (100%) at presentation. In 90% of instances, coughing and crackles were seen, making them extremely common. In 76.7% of patients, chest indrawing was seen, and in 80% of cases, wheezing was reported. Other symptoms were sleep difficulties in 36.7%, hypoxia (SpO₂ < 93%) in 43.3%, and unwillingness to feed (56.7%). Lethargy, stridor, or grunting (each 26.7%), decreased air entry (26.7%), cyanosis (13.3%), and altered sensorium (10%) were less common symptoms.

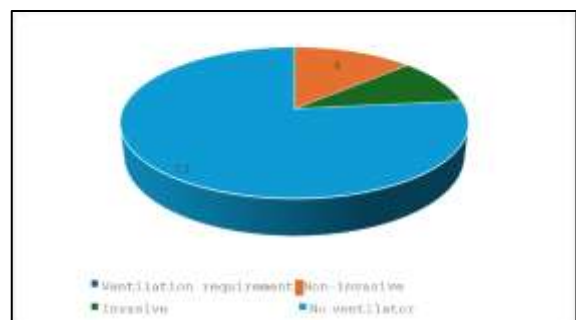


Figure 9: Ventilation requirement

Table 9: Ventilation requirement

Ventilation requirement	Cases (N = 30)
Non-invasive	4 (13.3%)
Invasive	3 (10%)
No ventilator	23 (76.7%)
Total	30 (100%)

In terms of ventilation requirements, most cases (76.7%) did not require ventilator support. Non-invasive ventilation was needed in 13.3% of cases (4 individuals), while 10% of cases (3 individuals)

required invasive ventilation. This distribution reflects a relatively low need for advanced respiratory support in the patient group.

Table 10: Distribution of Mean Zinc Values Among Cases and Controls

Zinc level in cases and controls	Mean ± SD	P Value
Cases	62.34 ± 28.16	0.001 (<0.05)
Controls	81.68 ± 27.65	

Cases had a mean zinc level of 62.34 ± 28.16 (µg/dl), which was much lower than the control group's 81.68 ± 27.65 (µg/dl). With a p-value of 0.001, this

difference was statistically significant, suggesting a possible link between the case group's illness and lower zinc levels.

Table 11: Zinc level distribution age-wise in cases

Zinc level distribution age wise	Mean ± SD	P Value
<12 months	61.48 ± 24.69	0.851 (>0.05)
12-36 months	63.78 ± 29.67	
26-59 months	53.56 ± 31.75	

There was no statistically significant variation in zinc levels between the age groups, according to the p-value of 0.851.

Table 12: Zinc level distribution age-wise in controls

Zinc level distribution agewise	Mean ± SD	P Value
<12 months	79.21 ± 25.84	0.951 (>0.05)
12-36 months	83.12 ± 21.78	
26-59 months	84.67 ± 19.54	

As people mature, the variability (SD) declines. There is no discernible difference in zinc levels between the <12 month group and the others, as

indicated by the p-value of 0.951 (>0.05). Complete statistical comparison is not possible for the older groups due to missing p-values.

Table 13: Zinc levels distribution sex-wise in cases

Zinc levels distribution sexwise	Mean ± SD	P Value
Male	60.95 ± 26.34	0.864 (>0.05)
Female	61.95 ± 30.86	

Male and female zinc levels did not differ statistically significantly, according to the p-value of 0.864.

Table 14: Zinc levels distribution sex-wise in controls

Zinc levels distribution sexwise	Mean ± SD	P Value
Male	82.48 ± 24.94	0.745 (>0.05)
Female	84.31 ± 18.34	

Mean ± standard deviation of zinc levels was 84.31 ± 18.34 µg/dL for females and 82.48 ± 24.94 µg/dL for males. There is no statistically significant difference

in zinc levels between the sexes, according to the p-value of 0.745 (>0.05).

Table 15: Anthropometry of Subjects and Controls

Anthropometry	Cases (N = 30)	Controls (N = 30)	χ ²	P-Value
Weight-for-age %			17.94	0.001
≤80	10 (33.3%)	3 (10%)		
>80	20 (66.7%)	27 (90%)		
Height-for-age %			12.495	0.001
<95	13 (43.3%)	8 (26.7%)		
≥95	17 (56.7%)	22 (73.3%)		
Weight-for-height %			6.359	0.007
<90	14 (46.7%)	8 (26.7%)		
≥90	16 (53.3%)	22 (73.3%)		

In all three parameters, the anthropometric measures showed a substantial difference between the cases and controls. In comparison to just 10% of controls, 33.3% of patients had a weight-for-age percentage ≤80 (χ² = 17.94, p = 0.001). In relation to height-for-height-for-age percentage <95 was present in 43.3% of cases and 26.7% of controls (χ² =

12.495, p = 0.001). Compared to 26.7% of controls, 46.7% of cases had a percentage <90 for weight-for-height (χ² = 6.359, p = 0.007). According to these findings, anthropometric measurements were lower in cases than in controls, and all differences were statistically significant.

Table 16: Anthropometry of Subjects and Controls with mean Serum Zinc levels

Anthropometry	Cases Mean ± SD	Controls Mean ± SD	P Value
Weight-for-age %			
≤80	69.47 ± 19.25	76.78 ± 24.26	0.0001
>80	70.28 ± 17.54	87.16 ± 21.59	0.001

Height-for-age %			
<95	57.77 ± 24.65	84.64 ± 15.69	0.0001
≥95	62.22 ± 28.56	90.37 ± 19.64	0.0001
Weight-for-height %			
<90	64.58 ± 14.56	73.25 ± 26.45	0.001
≥90	67.99 ± 19.84	85.29 ± 21.68	0.001

Anthropometric measurements, classified by weight-for-age, height-for-age, and weight-for height percentages, were compared between patients and controls in the study. All categories showed significant differences, with controls continuously showing higher mean values than cases. For weight-for-age, controls had higher percentages in both ≤80% (76.78 ± 24.26 vs. 69.47 ± 19.25, p = 0.0001) and >80% (87.16 ± 21.59 vs. 70.28 ± 17.54, p = 0.001) categories. Similarly, for height-for-age,

controls outperformed cases in both <95% (84.64 ± 15.69 vs. 57.77 ± 24.65, p = 0.0001) and ≥95% (90.37 ± 19.64 vs. 62.22 ± 28.56, p = 0.0001) groups. In the weight-for-height category, controls again exhibited higher percentages in both <90% (73.25 ± 26.45 vs. 64.58 ± 14.56, p = 0.001) and ≥90% (85.29 ± 21.68 vs. 67.99 ± 19.84, p = 0.001) subgroups. The data highlight significant anthropometric deficits in cases compared to controls, underscoring the disparities in nutritional and health outcomes.

Table 17: Serum Zinc Levels and Related Laboratory Parameters in Subjects and Controls

Parameter	Cases (N =30)	Controls (N =30)	T Value	P Value
Serum Zinc (µg/dL)			16.812	0.001
Range	3.9 - 94.4	19.5 - 111.8		
Mean (SD)	19.2 (11.2)	53.1 (18.5)		
Serum Total Protein (g/L)			-0.875	0.426
Range	39.0 - 99	48.0 - 103		
Mean (SD)	71.5 (12.2)	73.1 (13.1)		
Serum Albumin (g/L)			-4.954	0.001
Range	26.5 - 56.5	31.2 - 57.9		
Mean (SD)	39.7 (6.9)	44.4 (7.7)		
Serum CRP (mg/L)			19.561	0.001
Range	1.3 - 75	0.9 - 7.0		
Mean (SD)	28.6 (17.8)	2.90 (1.5)		

There were notable variations in the biochemical parameters between the controls and the patients. With a mean of 19.2 µg/dL (SD = 11.2), serum zinc levels were significantly lower in cases than in controls (53.1 µg/dL, SD = 18.5) (t = 16.812, p < 0.001). With a mean of 71.5 g/L (SD = 12.2) for the patients and 73.1 g/L (SD = 13.1) for the controls, the two groups' serum total protein levels were comparable, and there was no discernible difference (t = -0.875, p = 0.426). Cases had significantly lower

serum albumin levels (mean = 39.7 g/L, SD = 6.9) than controls (mean = 44.4 g/L, SD = 7.7) (t = -4.954, p = 0.001). Lastly, serum C-reactive protein (CRP) levels were markedly higher in cases (mean = 28.6 mg/L, SD = 17.8) compared to controls (mean = 2.9 mg/L, SD = 1.5), showing a significant difference (t = 19.561, p = 0.001). These results suggest lower zinc and albumin levels, and higher CRP levels in cases, indicative of nutritional deficiencies and inflammatory responses.

Table 18: Zinc Status of the Study Population

Zinc Status	Cases (N =30)	Controls (N = 30)	Total	OR (95% CI)	P Value
Low Serum Zinc	29 (96.7%)	18 (60%)	47 (78.3%)	19.33 (2.31-161.57)	0.006
Normal Serum Zinc	1 (3.3%)	12 (40%)	13 (21.7%)		
Total	30 (100%)	30 (100%)	60 (100%)		

The zinc status of the patients and controls in this investigation differed substantially. Compared to 60% of controls, most cases (96.7%) had low serum zinc levels. Serum zinc levels were normal in 40% of controls and only 3.3% of cases. 78.3% of participants in the research had low serum zinc levels

overall. With an odds ratio (OR) of 19.33 (95% CI: 2.31 - 161.57) and a p-value of 0.006, the case group had a considerably higher chance of having low serum zinc than the controls. This suggests a strong correlation between the case group and poor zinc status.

Table 19: Serum Zinc Levels in ARI and Non-ARI (Control) Children

Serum Zinc (mmol/L)	Range	Cases (N = 30)	Controls (N = 30)	P- Value
1.00 to <17.00		9 (30%)	3 (10%)	p = 0.0002
17.00 to <27.00		9 (30%)	5 (16.7%)	
27.00 to <47.00		10 (33.3%)	4 (13.3%)	
47.00 to 122.00		2 (6.7%)	18 (60%)	
Total		30 (100%)	30 (100%)	

Serum zinc levels in cases and controls were distributed as follows: 30% of cases (9 individuals) had serum zinc levels ranging from 1.00 to <17.00 mmol/L, compared to only 10% of controls (3 individuals), with a significant difference ($p = 0.0002$). In the 17.00 to <27.00 mmol/L range, 30% of cases (9 individuals) and 16.7% of controls (5 individuals) were observed. For the 27.00 to <47.00 mmol/L range, 33.3% of cases (10 individuals) and 13.3% of controls (4 individuals) fell into this category. In contrast, 60% of controls (18 individuals) had serum zinc levels ranging from 47.00 to 122.00 mmol/L, while only 6.7% of cases (2 individuals) had levels in this range. According to these findings, patients' serum zinc levels were noticeably lower, with the biggest difference occurring in the lowest range.

DISCUSSION

Zinc deficiency compromises children's immune systems, significantly increasing their vulnerability to major global health threats like pneumonia and acute respiratory infections. Evidence connects low zinc levels to higher infection rates, positioning zinc supplementation as a crucial preventative and therapeutic strategy to reduce pediatric mortality. Zinc is essential for child development and immune function, driving cellular processes like DNA replication and the activation of key immune cells. In resource-limited settings, zinc deficiency compromises both innate and adaptive immunity, significantly increasing children's susceptibility to infections.

Zinc preserves epithelial barriers and drives the innate immune system's first-line *Défense* against pathogens. It regulates vital neutrophil and macrophage functions, including chemotaxis, phagocytosis, and the cytokine signalling necessary to coordinate immune responses. These frontline immune cells' efficacy is significantly reduced when zinc levels are low, which makes them more vulnerable to infection.^[12] Without sufficient zinc, these cells cannot effectively present antigens to T cells, resulting in compromised activation of the adaptive immune response.^[13]

Zinc serves as a vital cofactor for over 300 enzymes and regulates gene expression by interacting with key transcription factors like NF- κ B and interferon regulatory factors. During an infection, these zinc-dependent pathways control inflammation and trigger the transcription of proinflammatory cytokines to activate the immune system.^[14] Deficiency in zinc can lead to unchecked cell death or the persistence of ineffective immune cells, disrupting immune homeostasis and weakening the body's response to pathogens.^[15] Zinc deficiency is a global health issue that severely impairs both the innate and adaptive immune systems in children under five. This deficiency reduces the production and function of vital immune cells—including T

cells, B cells, and phagocytes—ultimately weakening antibody production and cytokine signaling needed to fight infections.^[16]

Zinc deficiency directly increases children's susceptibility to severe respiratory illnesses like pneumonia and acute respiratory infections. This weakened immune state not only elevates the risk of contracting infections but also prolongs recovery, extends hospital stays, and increases mortality rates.^[17] Chronic deficiencies caused by inadequate consumption of foods high in zinc or by inadequate absorption of zinc in the stomach can increase a child's susceptibility to infections.^[18]

Zinc deficiency in children can cause delayed or impaired wound healing, which may result in problems and worsen the consequences of infections.^[19] Severity of illnesses like pneumonia or respiratory tract infections may be increased in children with zinc deficiency due to an overactive inflammatory response brought on by improper immune modulation.^[20] A zinc shortage can result in stunted growth, delayed physical development, and cognitive impairment since zinc is necessary for healthy growth and development. Overall health and the immune system's capacity to perform at its best are closely related, and a zinc deficit that causes development delays.^[21] Zinc supplementation dramatically reduces the incidence of diseases including pneumonia, diarrheal disorders, and acute respiratory infections (ARIs) in children, particularly those who are deficient, according to empirical research.^[22]

Zinc improves clinical outcomes and shortens hospital stays by enhancing immunological activity, which enables a more effective reaction to infections. Administering zinc to at-risk pediatric populations may prevent the initial onset of illness and alleviate the broader public health burden.

CONCLUSION

This study demonstrates a significant correlation between low serum zinc levels and the incidence and severity of pediatric acute lower respiratory infections (ALRI), highlighting zinc's critical role in respiratory and immunological health. While nutritional status did not differ between groups, zinc deficiency emerged as a major independent contributor to ALRI alongside environmental and sociodemographic factors, including biomass fuel consumption, parental smoking, and lower maternal education. Consequently, targeted zinc supplementation and reduced environmental exposure represent viable, high-impact strategies to improve child health outcomes and mitigate ALRI burdens in resource-limited settings.

REFERENCES

1. Turner RB, Cetnarowski WE. Zinc treatment for the common cold and the risk of zinc toxicity in children. *J Pediatr*. 2000;136(4):538-539.

2. Ujunwa FA, Ezeonu CT. Risk factors for acute respiratory tract infections in under-five children in Enugu southeast Nigeria. *Ann Med Health Sci Res.* 2014;4(1):95-99.
3. Kumar S, Mangal DK, Panesar S, et al. Zinc supplementation for prevention of acute respiratory infections in infants: a randomized controlled trial. *Indian Pediatr.* 2011;48(11):867-873.
4. Haider BA, Bhutta ZA. The effect of therapeutic zinc supplementation among young children with selected infections: a review of the evidence. *Food Nutr Bull.* 2009;30(1 Suppl):S41-S59.
5. Brooks WA, Yunus M, Santosham M, et al. Zinc for severe pneumonia in very young children: double-blind placebo-controlled trial. *Lancet.* 2004;363(9422):1683-1688.
6. Sitthikarnkha P, Uppala R, Niamsanit S, Sutra S, Thepsuthammarat K, Techasatian L, Teeratakulpisarn J. Epidemiology of acute lower respiratory tract infection hospitalizations in Thai children: A 5-year national data analysis. *Influenza Other Respir Viruses.* 2022 Jan;16(1):142-150. doi: 10.1111/irv.12911. Epub 2021 Sep 15. PMID: 34523811; PMCID: PMC8692802.
7. Islam, S. N., Kamal, M. M., Rahmatullah, R., Sadi, S. K. S., & Ahsan, M. (2018). Serum zinc levels in children with acute respiratory infections: Association with sociodemography and nutritional status. *Clinical Nutrition Experimental*, 22, 11–18. <https://doi.org/10.1016/j.clnex.2018.09.002>
8. Ibraheem RM, Johnson AB, Abdulkarim AA, Biliaminu SA. Serum zinc levels in hospitalized children with acute lower respiratory infections in the north-central region of Nigeria. *Afr Health Sci.* 2014 Mar;14(1):136-42. doi: 10.4314/ahs.v14i1.21. PMID: 26060470; PMCID: PMC4449050.
9. Kumar N, Kumari A, Kumar R, Sahay AK. Zinc level estimation in children with acute lower respiratory tract infection: A case control study. *Int J Pharm Clin Res.* 2024;16(6):715-718. Available from: www.ijpcr.com
10. Rajasekaran J, Geminiganesan S, Jayapalan DK, Padmanaban R, Saminathan V. Serum Zinc Levels in Children 1 - 59 Months of Age with Pneumonia: A SingleCenter Surveillance in India from 2014 to 2016. *Arch Pediatr Infect Dis.* 2020;8(2):e98735. <https://doi.org/10.5812/pedinfec.98735>.
11. La QP, Lu DT, Le SH. Relationship between serum zinc levels and the burden of treatment in children with pneumonia. A cross-sectional study of awareness regarding dog bite and its management in rural community of Maharashtra, India. *Int J Contemp Pediatr* 2024;11:1177-82.
12. Prasad, A. S. (2014). Zinc: Role in immunity, oxidative stress, and chronic inflammation. *Current Opinion in Clinical Nutrition & Metabolic Care*, 17(6), 557-563.
13. Shankar, A. H., & Prasad, A. S. (1998). Zinc and immune function: The biological basis of altered resistance to infection. *The American Journal of Clinical Nutrition*, 68(2), 447S-463S.
14. Fenech, M., & Crott, J. W. (2005). Zinc and immune function: The key to inflammation? *British Journal of Nutrition*, 94(3), 405-407.
15. Hambidge, K. M., & Krebs, N. F. (2007). Zinc deficiency: A special challenge. *The Journal of Nutrition*, 137(4), 1101S-1103S.
16. Black, R. E. (2003). Zinc deficiency, infectious disease, and mortality in the developing world. *The Journal of Nutrition*, 133(5), 1485S-1489S.
17. Hulisz, D. (2004). Zinc and its role in immunity and inflammation. *Journal of Clinical Pharmacy and Therapeutics*, 29(1), 1-5.
18. Bhatnagar, S., & Meena, R. (2013). Zinc supplementation and immune function in children. *The Indian Journal of Pediatrics*, 80(7), 607-612.
19. Tang, A. M., & Yip, R. (2012). Zinc deficiency and immune function: A global perspective. *Nutrition Reviews*, 70(11), 659-668.
20. Zinc Deficiency and Immune Function in Children, World Health Organization. (2004). WHO Report.
21. Victora, C. G., et al. (2008). Zinc deficiency and its effect on childhood morbidity and mortality. *The American Journal of Clinical Nutrition*, 89(4), 1185-1190.
22. Gibson, R. S. (2006). Zinc and immune function: The role of zinc in the immune response. *The Journal of Clinical Nutrition*, 83(4), 876-885.