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Clinical and Nutritional Predictors of Recurrent Respiratory Tract Infections in Children Aged 2-10 Years: A Prospective Observational Study.

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Abstract

Background: Recurrent respiratory tract infections (RRTIs) are common in childhood and can reflect interacting clinical, nutritional, and environmental vulnerabilities. Identifying modifiable predictors can support targeted preventive care. ***Objectives:*** To determine the occurrence and pattern of RRTIs in children aged 2-10 years and identify independent clinical and nutritional predictors of recurrence. ***Methods:*** This prospective observational study included 80 children at Mamata Academy of Medical Sciences, Bachupally, Hyderabad, Telangana, India, from June to November 2025. Baseline anthropometry, haemoglobin, vitamin D, zinc status, allergic and respiratory history, breastfeeding history, and household tobacco-smoke exposure were recorded. Respiratory episodes were documented prospectively. Children were classified as having or not having RRTIs using predefined age-adapted clinical criteria. Multivariable logistic regression was used to identify independent predictors. ***Results:*** Thirty-one children (38.8%) developed RRTIs. The RRTI group experienced more respiratory episodes than the non-RRTI group (7.1 ± 1.4 vs 3.2 ± 1.1; p<0.001). Underweight, anaemia, vitamin D insufficiency/deficiency, low serum zinc, allergic rhinitis, recurrent wheezing, tobacco-smoke exposure, and shorter exclusive breastfeeding were associated with RRTI in univariate analysis. Independent predictors were underweight (aOR 3.21; 95% CI 1.08-9.55), anaemia (aOR 3.05; 95% CI 1.07-8.69), vitamin D insufficiency/deficiency (aOR 2.89; 95% CI 1.03-8.10), allergic rhinitis (aOR 3.34; 95% CI 1.09-10.25), and tobacco-smoke exposure (aOR 3.08; 95% CI 1.02-9.31). ***Conclusion:*** RRTIs were frequent and were independently associated with nutritional deficits, allergic rhinitis, and household tobacco-smoke exposure. Integrated nutritional and clinical risk assessment could strengthen prevention strategies in susceptible children.

Keywords: children; recurrent respiratory tract infections; underweight; anaemia; vitamin D; allergic rhinitis; tobacco smoke.

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INTRODUCTION

Respiratory tract infections are among the most frequent causes of childhood morbidity and health-care utilization. Young children commonly experience repeated viral upper respiratory infections because of ongoing immune maturation, expanding social contact, and repeated exposure in household and school environments. Although most episodes are self-limiting, a subgroup of children develops recurrent respiratory tract infections (RRTIs), resulting in repeated outpatient visits, antibiotic exposure, school absenteeism, parental work loss, and occasional hospitalization. The clinical definition of RRTI is not fully uniform across studies because frequency thresholds vary by age, anatomical site, severity, and duration of observation [1]. Contemporary reviews therefore emphasize a structured assessment that distinguishes otherwise healthy children with frequent uncomplicated infections from those with chronic disease, anatomical abnormalities, or immune disorders [1,2].

Susceptibility to recurrent infection is multifactorial. Age, early school or day-care contact, atopic disease, wheezing disorders, upper-airway pathology, household crowding, and environmental tobacco smoke can alter exposure or host responses [2-4]. A recent meta-analysis identified asthma, shorter breastfeeding duration, day-care attendance, siblings, environmental tobacco smoke, and snoring among factors associated with RRTIs in children [4]. Allergic inflammation and recurrent wheeze can impair mucosal function and increase symptom burden during viral infections, while tobacco-smoke exposure disrupts respiratory epithelial defense and is consistently associated with lower respiratory illness in childhood [13].

Nutritional status is another potentially modifiable component. Protein-energy undernutrition and micronutrient deficiencies can compromise innate and adaptive immune responses. Vitamin D participates in epithelial barrier function and antimicrobial signaling, and low circulating 25-hydroxyvitamin D concentrations have been reported frequently among children with recurrent respiratory infections [5,6]. Evidence from supplementation trials is mixed, although several meta-analyses suggest that the effect of vitamin D on acute respiratory infection varies with dose, regimen, age, and baseline status [7,8]. Zinc supports epithelial integrity and cellular immunity, and supplementation has shown modest reductions in childhood respiratory morbidity in pooled analyses [9]. Iron deficiency can also alter humoral and innate immune function, providing biological plausibility for an association between anaemia and recurrent infection [10].

Breastfeeding provides immunological and nutritional protection during early life and is associated with lower childhood infection burden [11,12]. These observations suggest that RRTIs should be evaluated using an integrated clinical, nutritional, and environmental framework rather than as isolated infectious events. The present study was therefore undertaken to determine the occurrence and pattern of recurrent respiratory tract infections among children aged 2-10 years and to evaluate clinical and nutritional factors associated with recurrence. The specific objective was to identify independent predictors of RRTI, with particular attention to anthropometric status, anaemia, vitamin D status, zinc status, allergic rhinitis, recurrent wheezing, household tobacco-smoke exposure, and breastfeeding history.

METHODOLOGY

Study design and setting. This prospective observational study was conducted in the Department of Paediatrics, Mamata Academy of Medical Sciences, Bachupally, Hyderabad, Telangana, India, from June 2025 to November 2025. Eighty children aged 2-10 years were enrolled at baseline and followed prospectively for respiratory infection episodes during the study period. Necessary Permissions were obtained before starting the study. Written informed consent was obtained from a parent or legally authorized guardian before enrolment.

Study population. Children aged 2-10 years attending paediatric services and whose caregivers were willing to participate and comply with follow-up were eligible. Children with known primary or secondary immunodeficiency, cystic fibrosis, primary ciliary dyskinesia, active tuberculosis, major congenital cardiopulmonary disease, chronic renal or hepatic disease, malignancy, or ongoing systemic immunosuppressive therapy were excluded because these conditions independently influence infection frequency. Children with incomplete baseline nutritional assessment or inadequate follow-up documentation were also excluded. A consecutive sample of 80 eligible children completing the planned observation was analysed.

Clinical and nutritional assessment. At enrolment, demographic data, breastfeeding history, respiratory and allergic history, recurrent wheezing, adenotonsillar hypertrophy, and household environmental tobacco-smoke exposure were recorded using a structured case-record form. Weight and standing height were measured using calibrated equipment. Body mass index was calculated and converted to age- and sex-specific Z scores using World Health Organization growth standards/references; underweight or thinness and stunting were identified using values below -2 SD for the corresponding anthropometric index [14]. Complete blood count, serum 25-hydroxyvitamin D, and serum zinc were obtained at baseline. Anaemia was classified using age-appropriate haemoglobin thresholds. Vitamin D insufficiency/deficiency was defined as a serum 25-hydroxyvitamin D concentration below 30 ng/mL, while low zinc status was classified according to the age-appropriate lower reference limit used by the institutional laboratory.

Outcome assessment. Respiratory episodes were documented prospectively from clinical records and scheduled caregiver contacts. Upper and lower respiratory infections, pharyngotonsillitis, otitis/sinus-related infections, antibiotic use, and respiratory-related hospitalization were recorded. RRTI classification followed predefined age-adapted clinical criteria informed by contemporary pediatric consensus, incorporating episode frequency, duration, anatomical diagnosis, and symptom-free intervals rather than relying on a single threshold across all ages [1,3]. Children were subsequently categorized into RRTI and non-RRTI groups.

Statistical analysis. Continuous variables were summarized as mean ± standard deviation and categorical variables as frequency and percentage. Between-group comparisons used the independent-samples t test for continuous variables and Pearson chi-square test for categorical variables, as appropriate. Variables showing an association with RRTI in univariate analysis, together with clinically relevant age and sex covariates, were considered for multivariable binary logistic regression. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were reported. A two-sided p value <0.05 was considered statistically significant.

RESULTS

Participant characteristics

A total of 80 children aged 2-10 years were analysed. Their mean age was 6.1 ± 2.3 years and 44 (55.0%) were boys. Underweight was present in 19 (23.8%) children, stunting in 13 (16.3%), anaemia in 25 (31.3%), vitamin D insufficiency/deficiency in 30 (37.5%), and low serum zinc in 18 (22.5%). Allergic rhinitis was documented in 21 (26.3%), recurrent wheezing in 16 (20.0%), and household tobacco-smoke exposure in 24 (30.0%). Forty-nine children (61.3%) had received exclusive breastfeeding for at least six months (Table 1).

Table 1. Baseline clinical and nutritional characteristics of the study population (n = 80)

Characteristic	Value
Age, years, mean ± SD	6.1 ± 2.3
Male sex, n (%)	44 (55.0)
Female sex, n (%)	36 (45.0)
BMI-for-age Z score, mean ± SD	-0.74 ± 1.12
Underweight, n (%)	19 (23.8)
Stunting, n (%)	13 (16.3)
Anaemia, n (%)	25 (31.3)
Vitamin D insufficiency/deficiency, n (%)	30 (37.5)
Low serum zinc, n (%)	18 (22.5)
Allergic rhinitis, n (%)	21 (26.3)
Recurrent wheezing, n (%)	16 (20.0)
Adenotonsillar hypertrophy, n (%)	14 (17.5)
Environmental tobacco-smoke exposure, n (%)	24 (30.0)
Exclusive breastfeeding ≥6 months, n (%)	49 (61.3)

Occurrence and pattern of recurrent respiratory tract infections

During prospective follow-up, 31 of 80 children (38.8%) fulfilled the predefined criteria for RRTI, whereas 49 (61.3%) were classified as non-RRTI. The overall mean number of respiratory infection episodes was 4.7 ± 2.3 per child. Children in the RRTI group experienced substantially more episodes than those in the non-RRTI group (7.1 ± 1.4 vs 3.2 ± 1.1; p<0.001). Upper respiratory infections predominated. Among children with RRTI, 22 (71.0%) experienced repeated acute upper respiratory tract infections, 13 (41.9%) had recurrent pharyngotonsillitis, 10 (32.3%) developed recurrent otitis or sinus-related infection, and 8 (25.8%) experienced at least one lower respiratory tract infection.

The clinical burden was also greater in the RRTI group. Lower respiratory infection, recurrent pharyngotonsillitis, recurrent otitis/sinus-related infection, repeated antibiotic treatment, and hospital admission for respiratory illness were all more frequent among children with RRTI. Antibiotic treatment on at least three occasions was documented in 18 (58.1%) children with RRTI compared with 9 (18.4%) children without recurrence (p<0.001). Seven (22.6%) children in the RRTI group required hospital admission for respiratory illness compared with 3 (6.1%) in the non-RRTI group (p=0.031) (Table 2).

Table 2. Respiratory infection pattern and clinical burden during follow-up

Outcome	RRTI group (n = 31)	Non-RRTI group (n = 49)	p-value
Respiratory infection episodes, mean ± SD	7.1 ± 1.4	3.2 ± 1.1	<0.001
≥1 lower respiratory tract infection, n (%)	8 (25.8)	4 (8.2)	0.032
Recurrent pharyngotonsillitis, n (%)	13 (41.9)	7 (14.3)	0.005
Recurrent otitis/sinus-related infection, n (%)	10 (32.3)	5 (10.2)	0.013
Antibiotic treatment on ≥3 occasions, n (%)	18 (58.1)	9 (18.4)	<0.001
Hospital admission for respiratory illness, n (%)	7 (22.6)	3 (6.1)	0.031

Clinical and nutritional factors associated with recurrent infections

Several nutritional abnormalities were more common among children who developed RRTI. Underweight status occurred in 12 (38.7%) children in the RRTI group compared with 7 (14.3%) in the non-RRTI group (p=0.012). Anaemia was present in 15 (48.4%) versus 10 (20.4%) children, respectively (p=0.008). Vitamin D insufficiency or deficiency was recorded in 17 (54.8%) children with RRTI compared with 13 (26.5%) without RRTI (p=0.011), while low serum zinc was present in 11 (35.5%) versus 7 (14.3%) children (p=0.027). Stunting was more frequent in the RRTI group, but the difference did not reach statistical significance.

Among clinical and environmental factors, allergic rhinitis, recurrent wheezing, and environmental tobacco-smoke exposure were significantly more frequent in the RRTI group. Allergic rhinitis was observed in 41.9% versus 16.3% (p=0.010), recurrent wheezing in 32.3% versus 12.2% (p=0.027), and tobacco-smoke exposure in 45.2% versus 20.4% (p=0.018). Exclusive breastfeeding for at least six months was less frequent among children with RRTI (45.2% vs 71.4%; p=0.019). Age below five years, male sex, stunting, and adenotonsillar hypertrophy were not statistically significant in the unadjusted comparison (Table 3).

Table 3. Comparison of potential predictors according to recurrent respiratory tract infection status

Predictor	RRTI (n = 31)	Non-RRTI (n = 49)	p-value
Age <5 years, n (%)	15 (48.4)	14 (28.6)	0.073
Male sex, n (%)	19 (61.3)	25 (51.0)	0.369
Underweight, n (%)	12 (38.7)	7 (14.3)	0.012
Stunting, n (%)	8 (25.8)	5 (10.2)	0.064
Anaemia, n (%)	15 (48.4)	10 (20.4)	0.008
Vitamin D insufficiency/deficiency, n (%)	17 (54.8)	13 (26.5)	0.011
Low serum zinc, n (%)	11 (35.5)	7 (14.3)	0.027
Allergic rhinitis, n (%)	13 (41.9)	8 (16.3)	0.010
Recurrent wheezing, n (%)	10 (32.3)	6 (12.2)	0.027
Adenotonsillar hypertrophy, n (%)	8 (25.8)	6 (12.2)	0.116
Tobacco-smoke exposure, n (%)	14 (45.2)	10 (20.4)	0.018
Exclusive breastfeeding ≥6 months, n (%)	14 (45.2)	35 (71.4)	0.019

Independent predictors of recurrent respiratory tract infections

In multivariable logistic regression, underweight status, anaemia, vitamin D insufficiency/deficiency, allergic rhinitis, and household tobacco-smoke exposure remained independently associated with RRTI. Adjusted odds ratios ranged from 2.89 for vitamin D insufficiency/deficiency to 3.34 for allergic rhinitis. Underweight (aOR 3.21), anaemia (aOR 3.05), and tobacco-smoke exposure (aOR 3.08) also showed approximately threefold higher adjusted odds of recurrence. Low zinc, recurrent wheezing, and exclusive breastfeeding for at least six months were not statistically significant after adjustment (Table 4).

Table 4. Multivariable logistic regression analysis of predictors of recurrent respiratory tract infections

Predictor	Adjusted OR	95% CI	p-value
Underweight	3.21	1.08-9.55	0.036
Anaemia	3.05	1.07-8.69	0.037
Vitamin D insufficiency/deficiency	2.89	1.03-8.10	0.044
Low serum zinc	2.38	0.78-7.24	0.128
Allergic rhinitis	3.34	1.09-10.25	0.035
Recurrent wheezing	2.37	0.72-7.79	0.156
Tobacco-smoke exposure	3.08	1.02-9.31	0.046
Exclusive breastfeeding ≥6 months	0.48	0.17-1.36	0.168

Overall, RRTIs affected slightly more than one-third of the study population. The final adjusted model identified a combination of nutritional vulnerability, allergic airway disease, and household smoke exposure as the principal independent predictors of recurrence.

DISCUSSION

The present prospective study found that 38.8% of children developed recurrent respiratory tract infections during follow-up, indicating a substantial burden in this hospital-based pediatric population. The frequency is higher than estimates reported in some community populations, but direct comparison is difficult because RRTI definitions, age ranges, referral patterns, and observation periods vary considerably [1,3]. This heterogeneity is well recognized in pediatric literature. Cardinale et al. emphasized that recurrent infections usually reflect the cumulative influence of host, environmental, atopic, and nutritional factors rather than a single abnormality [2]. The current findings support that multidimensional interpretation.

Underweight status emerged as an independent predictor, with more than threefold higher adjusted odds of RRTI. Poor nutritional status can compromise epithelial integrity, cellular immune responses, and recovery from infection, creating a reciprocal cycle in which repeated illness further worsens nutritional intake and growth. Zinc deficiency was more frequent

in the RRTI group on univariate analysis, although it lost statistical significance after multivariable adjustment. This pattern is biologically plausible because zinc contributes to mucosal barrier function and immune-cell activity. A meta-analysis by Aggarwal et al. found that zinc supplementation produced modest reductions in respiratory illness frequency and a greater reduction in severe lower respiratory infection or pneumonia among children [9].

Anaemia also remained independently associated with recurrence. Children with iron deficiency anaemia have demonstrated alterations in immunoglobulin concentrations, phagocytic activity, neutrophil oxidative burst, and cytokine responses [10]. These mechanisms provide a credible explanation for the observed relationship, although anaemia in a clinical population can have multiple nutritional and inflammatory causes. Vitamin D insufficiency or deficiency was another independent predictor. Indian hospital-based data have similarly shown a high prevalence of subnormal vitamin D levels among children with recurrent respiratory infections [5], and recent pediatric observational evidence has linked lower 25-hydroxyvitamin D concentrations with recurrent infection [6]. However, supplementation evidence remains heterogeneous: earlier individual-participant meta-analysis suggested protection against acute respiratory infection [7], whereas the updated 2025 analysis found no overall statistically significant protection and highlighted variation across populations and treatment regimens [8]. Thus, vitamin D status is best interpreted as one component of broader risk assessment.

Allergic rhinitis and household tobacco-smoke exposure were significant independent clinical predictors. Atopic airway inflammation can increase respiratory symptoms, impair local defense, and overlap clinically with viral illness. The large meta-analysis by Wang et al. identified asthma and environmental tobacco smoke among important RRTI risk factors [4]. Consistently, passive smoke exposure has been associated with increased lower respiratory infection in children [13]. Exclusive breastfeeding for at least six months was less frequent among children with RRTI in unadjusted analysis, but the association did not remain independent after adjustment. Breastfeeding nevertheless has established infection-related benefits [11,12]. Collectively, these findings favor integrated screening for growth, haematological and micronutrient abnormalities, allergic disease, and avoidable household smoke exposure when children present with repeated respiratory infections.

Limitations

This study has several limitations. The sample size was modest and recruitment from a single tertiary-care institution limits external generalizability. The six-month observation period did not capture a complete annual seasonal cycle. Some exposures, including breastfeeding history and household tobacco smoke, depended on caregiver reporting and were vulnerable to recall error. Residual confounding from socioeconomic conditions, diet, crowding, school attendance, and unmeasured immune factors also remains possible.

CONCLUSION

Recurrent respiratory tract infections affected more than one-third of children aged 2-10 years in this prospective cohort. Underweight status, anaemia, vitamin D insufficiency or deficiency, allergic rhinitis, and household tobacco-smoke exposure were independently associated with recurrence. Low zinc status, recurrent wheezing, and shorter exclusive breastfeeding showed important unadjusted associations but were not retained as independent predictors after multivariable adjustment. These findings support a broad clinical approach to children with repeated respiratory infections that extends beyond treatment of individual episodes. Routine assessment of growth, haemoglobin and selected micronutrients, recognition of allergic airway disease, breastfeeding promotion, and elimination of household tobacco-smoke exposure could help identify modifiable risks and guide targeted preventive care.

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