Effect of immunonutritional status, healthcare factors, and lifestyle on acute respiratory infections among under-5 children in Bangladesh

Md. Mustafa Kamal[1], Farina Aziz[2,3], Md. Rabiul Islam[2,4] (iD), Monira Ahsan[3] and Sheikh Nazrul Islam[5]

Abstract

Introduction: Acute respiratory infection is a major cause of death for under-5 children in Bangladesh. We aimed to analyze the effect of immunonutritional status, healthcare factors, and lifestyle on the incidence of acute respiratory infection among under-5 children taking individual-level and contextual-level risk factors into consideration.

Methods: This study recruited 200 children suffering from acute respiratory infection and 100 healthy controls matched by age, sex, and sociodemographic profile. Serum antioxidant vitamin A (retinol), vitamin C (ascorbic acid), and vitamin E (α-tocopherol) were assessed along with the impact of vaccination, socioeconomic factors, and Z-score on the incidence of acute respiratory infection.

Results: Serum antioxidant vitamins were significantly lower in the acute respiratory infection children compared to the non–acute respiratory infection group. Vitamin A was found to be significantly high in acute respiratory infection children who were breastfed for more than 1 year. Vitamin E levels were found to be significantly higher in the acute respiratory infection children who were immunized. Compared to the children living in tin-shed house or huts, serum vitamin E level increased in those acute respiratory infection children who resided in apartments. Vitamin A level was significantly high in those acute respiratory infection children whose height-for-age was −2 SD and above (Z-score), and vitamin C levels were also significantly high in those acute respiratory infection children whose weight-for-height was −2 SD and below (Z-score).

Conclusion: Deficiencies of antioxidant vitamins along with healthcare and lifestyle factors have a significant influence on the incidence of acute respiratory infection among under-5 children in Bangladesh.

Keywords

Immunonutrient, healthcare factors, lifestyle, acute respiratory infection, Bangladesh

Introduction

Acute respiratory infection (ARI) is a major public health problem affecting young children worldwide.[1] It is a leading cause of morbidity and mortality in children; particularly in developing countries, the mortality rate is 30–70 times higher than in developed countries.[2–5] In each year, ARI is responsible for nearly 4 million deaths and the leading cause of death for under-5 children in developing countries.[6] Every year, 15 million under-5 children surrender to death in the developing countries and ARI accounts for one-third of these deaths.[7–10] It is frequently surpassing diarrheal diseases and every year more than 4 million children (>10,000 per day) die of ARI worldwide.[11] It has been

[1]Department of Biochemistry, National Institute of Preventive and Social Medicine, Dhaka, Bangladesh
[2]Department of Pharmacy, University of Asia Pacific, Dhaka, Bangladesh
[3]Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Dhaka, Dhaka, Bangladesh
[4]Department of Clinical Pharmacy and Pharmacology, Faculty of Pharmacy, University of Dhaka, Dhaka, Bangladesh
[5]Institute of Nutrition and Food Science, University of Dhaka, Dhaka, Bangladesh

Corresponding author:
Md. Rabiul Islam, Department of Pharmacy, University of Asia Pacific, 74/A Green Road, Farmgate, Dhaka 1205, Bangladesh.
Email: robi.ayaan@gmail.com

reported that Bangladesh, India, Indonesia, and Nepal together account for 40% of the global ARI mortality.[12] Every day, 400 children die of ARI in Bangladesh and about 19% of all under-5 child deaths are linked to ARI.[9]

Nutrients from food source or supplementation are considered as key factors for oxidative stress and immunity in human.[13–15] Immunonutrients possess the ability to modulate the immune regulatory responses by interventions with specific nutrients. Vitamin A, C, and E are important antioxidant immunonutrients having potential immune-enhancing properties. Vitamin E is found to protect cells against lipid peroxidation, increase the production of total T-lymphocytes and T-helper marker, and enhance lymphocyte proliferation.[16] Vitamin E has been further associated with reducing prostaglandin production and lipid peroxidation in the immune cells, as well as enhanced cell-mediated immunity.[16–18] Vitamin C is a quencher of free-radicals and singlet oxygen and it can also regenerate vitamin E.[19] Vitamin C stimulates leukocyte functions including neutrophils motility, phagocytosis, delayed hypersensitivity, and antimicrobial activity.[20] Vitamin C deficiency has been noted to reduce T-lymphocyte-mediated activity and cell-mediated cytotoxicity. It is also associated with chemotactic function by reducing intra- and extracellular reactive oxygen species (ROS) and plays a unique role in protecting vitamin A and E.[17,21] The immunoenhancing property of antioxidant vitamins is attributable to their antioxidant activity.[22–25] Vitamin A supplementation enhances immune responses including antigen-specific T-lymphocyte proliferation, antibody production, and resistance to infection.[26–29]

It is evident from numerous sources that multiple immunonutrient deficiencies are associated with ARI, diarrhea, and other infections.[30–32] Immunonutrients possess the ability to modulate and regulate immune responses by interventions with specific nutrients. Vitamin A, E, and C are important antioxidant immunonutrients having potential immune-enhancing properties. Supplementation of immunonutrient has been observed to significantly reduce ARI-specific morbidity and mortality,[33–35] but there has been some dubiety regarding this outcome.[36,37] However, deficiencies of the micronutrients contribute to the development of immunodeficiency and multiple disorders.[38–41] Although several types of research on ARI, particularly on its incidence, prevalence, and management, have been carried out worldwide, studies relating the role of immunonutritional status on the occurrence of ARI are too scarce to be found. Therefore, attempts have been made, in this study, to investigate the immunonutritional profile, healthcare, lifestyle, and socioeconomic factors of the ARI-affected children and the possible correlation of these factors with the incidence of ARI.

Materials and methods

Study population

This is a prospective case–control study conducted at the pediatrics department of Dhaka Medical College Hospital (DMCH), Dhaka, Bangladesh, from May 2017 to April 2018. We selected DMCH for our study place as it is the country's leading tertiary care teaching hospital and patients are frequently admitted here from different parts of Bangladesh. The sample size was calculated based on the standard method as described by World Health Organization (WHO) and International Development Research Centre (IDRC) (1991). We expected that alpha risk and exposed controls will be 5% and 15%, respectively. To detect an odds ratio of 3, we designed a 1:2 matched case–control study with 95% power. The estimated total sample was 276 (184 cases and 92 controls) based on the above assumptions. Thus, this study recruited 200 children (aged 6–59 months) suffering from ARI and 100 non-ARI healthy children having similar age, sex, and socioeconomic backgrounds as cohort controls. The main clinical features considered for the diagnosis of ARI in the children were cough, fever, rapid respiration, chest indrawing, and culture test.

A questionnaire was prepared and subjected to a preliminary test among 50 hospitalized ARI children, who were excluded from the study population. The questionnaire was used only for this study as a pilot test (see the Supplemental Material). Immunization history (such as BCG, DPT, Polio, and Measles), as well as a history of colostrum and breastfeeding practices of the ARI children along with supplementation of high potency vitamin A capsule, was also investigated. Exclusion criteria included a history of diarrhea or other infectious diseases; known or suspected cases of renal, heart, and liver diseases; bone marrow hypoplasia; aplasia; autoimmune diseases such as systemic lupus erythematosus (SLE); and cancer. Children who were being treated with gold, antimalarial drugs, immunosuppressants, and phenylbutazone were also excluded. The socioeconomic status including information on education, occupation, income, and housing conditions was collected by a physician for both ARI and non-ARI children. The study was designed to analyze serum concentrations of antioxidant vitamins (A, C, and E) of ARI children.

Biochemical analysis

The venous blood sample was collected aseptically from each of the case and control subjects, and the blood specimen was subjected to centrifugation (3000 r/min, 10 min) to extract serum. A part of the serum was treated with trichloroacetic acid (TCA) for analysis of vitamin C. The remaining serum was aliquot into Eppendorf tubes and stored at −20°C for analysis of vitamin A and E as retinol and α-tocopherol. Reversed-phase high-performance liquid chromatography (HPLC, LC-10AD; Shimadzu, Japan) was used for the simultaneous determination of serum vitamin A and E.[42] The analytes vitamin A and E were isolated from the serum by liquid–liquid extraction using *n*-hexane, concentrated by evaporation under a nitrogen stream and reconstituted with HPLC-grade ethanol. The reconstituted sample (50 μL) was then injected into the HPLC instrument. A reverse-phase

Table 1. Serum concentration of vitamin E, C, and A of ARI ($N=200$) and non-ARI ($N=100$) children.

Antioxidant vitamin (µmol/L)	ARI children		Non-ARI children		p-value*
	% (n)	Mean ± SD	% (n)	Mean ± SD	
Vitamin E					
0.00–4.9	64.5 (129)	4.45 ± 4.05	54.0 (54)	6.51 ± 5.12	$t=3.86$
5.0–9.9	27.0 (54)		33.0 (33)		$p<0.001$
10.0–14.9	5.0 (10)		6.0 (6)		
15.0–19.9	1.5 (3)		3.0 (3)		
20.0–30.0	2.0 (4)		4.0 (4)		
Vitamin C					
4.0–9.9	21.5 (43)	25.36 ± 15.71	4.0 (4)	29.36 ± 12.75	$t=2.20$
10.0–19.9	16.0 (32)		28.0 (28)		$p=0.02$
20.0–29.9	28.0 (56)		34.0 (34)		
30.0–39.9	15.5 (31)		22.0 (22)		
40.0–60.0	19.0 (38)		12.0 (12)		
Vitamin A					
0.00–0.49	21.0 (42)	0.94 ± 0.77	11.0 (11)	1.28 ± 0.43	$t=4.15$
0.50–0.99	24.5 (49)		19.0 (19)		$p<0.001$
1.00–1.49	31.5 (63)		41.0 (41)		
1.50–1.99	10.5 (21)		25.0 (25)		
2.00–3.00	12.5 (25)		4.0 (4)		

ARI: acute respiratory infection; SD: standard deviation.
Every sample was analyzed twice to have replicate readings. Human antioxidant vitamin level in serum ranges—vitamin E: 22–29 µmol/L, vitamin A: 0.35–1.75 µmol/L, and vitamin C: 30–110 µmol/L.
*$p<0.05$.

shim-pack C_{18} CLC-ODS (M) column of diameter 4.6 mm (LC Column, 4.6 mm × 250 mm, No. 1256168; Shimadzu) was used with methanol: water (95:5) as mobile phase flowing at 1 mL/min, detector set at one attenuation. The column was re-equilibrated with the mobile phase for 5 min before the next injection. Vitamin A and E were detected spectrophotometrically at 291 nm. Every sample was injected consequently twice to have replicate chromatographs. Standard analytes were injected for every 25–30 test samples. Vitamin A and E were detected spectrophotometrically at 291 nm. Standard vitamin E, A, and C were purchased from Sigma Chemical Co. (USA) and solvents (HPLC grade) were purchased from Merck (Germany).

The serum, after extraction, was treated immediately with TCA and centrifuged at 3000 r/min for 10 min for vitamin C analysis. The clear supernatant thus obtained was stored at −20°C until analysis. Serum vitamin C was estimated using spectrophotometry with phenylhydrazine as an indicator.[43] Absorbance was measured against a reagent blank at 520 nm using a spectrophotometer (UV-1201, UV-vis; Shimadzu). Every sample was analyzed twice to have duplicate readings. Chemicals used in the analysis of serum vitamin C were purchased from Merck and Sigma Chemical Co.

Statistical analysis

SPSS software package (version 23.0; SPSS Inc., USA) was used to analyze the data. Descriptive statistics (frequencies, descriptive, crosstabs) and compare means (independent-samples t-test) were used to calculate all variables. Values were expressed as percentage, mean, and standard deviation. One-way analysis of variance (ANOVA, descriptive) and correlation (Pearson's and χ^2) were used to evaluate the influence of socioeconomic factors and healthcare facilities on the different parameters investigated.

Results

Results showed that serum vitamin A, C, and E levels in the ARI children were significantly low than that of non-ARI children (Table 1 and Figure 1). Vitamin A levels were found to be significantly low in the ARI children (0.94 ± 0.77 µmol/L) compared to non-ARI controls (1.28 ± 0.43 µmol/L) ($t=4.15$, $p<0.001$). Vitamin C content was significantly low in the ARI children (25.36 ± 15.71 µmol/L) compared to non-ARI controls (29.36 ± 12.75 µmol/L) ($t=2.20$, $p=0.02$). Serum concentrations of vitamin E were found to be 4.45 ± 4.05 µmol/L in the ARI children, while it was 6.51 ± 5.12 µmol/L in the non-ARI controls ($t=3.86$, $p<0.001$).

Effect of healthcare on the antioxidant vitamin status of children with ARI

DPT, Polio, colostrum, and vitamin A supplementation showed no influence on serum vitamin status (Table 2). BCG

and measles vaccination had a positive correlation vitamin E. Period of breastfeeding had positive correlation with vitamin A. The serum concentration of vitamin E was found to be significantly high in the ARI children who were immunized with BCG vaccine ($F(1, 198)=3.73$, $p=0.05$)
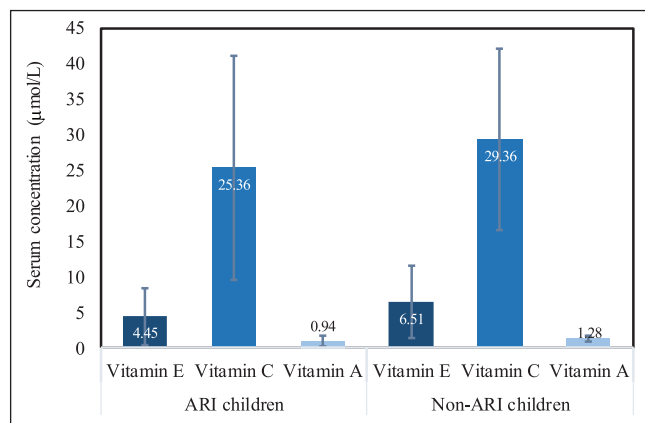
and measles vaccine ($F(1, 198)=5.63$, $p=0.01$). The serum concentration of vitamin A was found to be significantly high in the ARI children who were breastfed for more than 1 year ($F(1, 198)=5.53$, $p=0.02$).

Figure 1. Mean (SEM) concentration of serum antioxidant vitamins (E, C, and A) in ARI ($N=200$) and non-ARI ($N=100$) children.

Effect of lifestyle on the antioxidant vitamin status of children with ARI

Educational qualification and type of occupation of the parents did not influence the serum levels of vitamins A, C, and E (Table 3), but income and housing status had a significant impact on the serum levels of vitamin A and E. It was found that the income of the parents had a significant influence on vitamin A content of ARI children ($F(2, 197)=2.80$, $p=0.05$). Moreover, vitamin E level was high in those ARI children who resided in the apartments ($F(2, 197)=3.35$, $p=0.03$). As the age of the children with ARI increased, serum vitamin E ($F(3, 196)=2.70$, $p=0.04$) and C ($F(3, 196)=2.89$, $p=0.03$) levels significantly decreased. Z-scores (height-for-age and weight-for-height) had a significant influence on serum vitamin A and C levels (Table 3). The concentration of vitamin A was found to be significantly high in those ARI children whose height-for-age was –2 SD and above (Z-score) ($F(1, 197)=3.52$,

Table 2. Effect of healthcare factors on the antioxidant vitamin status of ARI children.

Parameters		% (n)	Vitamin E[a] Mean ± SD	Vitamin A[b] Mean ± SD	Vitamin C[c] Mean ± SD
BCG[1]					
	Yes	90.0 (180)	4.60 ± 4.13*	0.95 ± 0.77	25.20 ± 15.87
	No	10.0 (20)	2.77 ± 2.50*	0.82 ± 0.78	26.81 ± 14.41
DPT[2]					
	Yes	90.0 (180)	4.59 ± 4.13	0.95 ± 0.77	25.65 ± 15.72
	No	10.0 (20)	2.81 ± 2.48	0.78 ± 0.68	22.81 ± 15.71
Polio[3]					
	Yes	97.0 (194)	4.44 ± 4.03	0.94 ± 0.77	25.20 ± 15.72
	No	3.0 (6)	3.55 ± 2.30	89 ± 0.83	30.49 ± 15.58
Measles[4]					
	Yes	62.0 (124)	4.94 ± 4.52*	0.90 ± 0.71	24.79 ± 15.43
	No	38.0 (76)	3.56 ± 2.88*	0.99 ± 0.87	26.29 ± 16.20
Colostrum[5]					
	Yes	91.0 (182)	4.39 ± 4.07	0.93 ± 0.77	25.07 ± 15.84
	No	9.0 (18)	4.66 ± 3.42	1.01 ± 0.79	28.27 ± 14.35
Breast feeding (m)[6]					
	>12	53.0 (106)	4.45 ± 4.06	1.05 ± 0.77*	25.48 ± 15.85
	≤12	47.0(94)	3.59 ± 3.15	0.79 ± 0.76*	22.43 ± 12.12
Vitamin A supplementation[7]					
	Yes	68.5 (137)	4.47 ± 4.03	0.93 ± 0.78	24.81 ± 16.25
	No	31.5 (63)	4.29 ± 4.05	0.95 ± 0.76	26.57 ± 14.49

SD: standard deviation.
[1a]$F(1, 198)=3.73$, $p=0.05$; [1b]$F(1, 198)=0.47$, $p=0.49$; [1c]$F(1, 198)=0.18$, $p=0.66$; [2a]$F(1, 198)=3.56$, $p=0.06$; [2b]$F(1, 198)=0.86$, $p=0.35$; [2c]$F(1, 198)=0.58$, $p=0.44$; [3a]$F(1, 198)=0.28$, $p=0.59$; [3b]$F(1, 198)=0.01$, $p=0.89$; [3c]$F(1, 198)=0.65$, $p=0.41$; [4a]$F(1, 198)=5.63$, $p=0.01$; [4b]$F(1, 198)=0.68$, $p=0.41$; [4c]$F(1, 198)=0.42$, $p=0.51$; [5a]$F(1, 198)=0.07$, $p=0.78$; [5b]$F(1, 198)=0.18$, $p=0.66$; [5c]$F(1, 198)=0.67$, $p=0.41$; [6a]$F(1, 198)=0.34$, $p=0.55$; [6b]$F(1, 198)=5.53$, $p=0.02$; [6c]$F(1, 198)=0.28$, $p=0.59$; [7a]$F(1, 198)=0.08$, $p=0.76$; [7b]$F(1, 198)=0.03$, $p=0.86$; [7c]$F(1, 198)=0.54$, $p=0.46$.
*$p < 0.05$.

Table 3. Effect of socioeconomic factors and Z-scores on the vitamins of ARI children (N = 200).

Sociodemographic factors	% (n)	Vitamin E[a] (μmol/L)	Vitamin A[b] (μmol/L)	Vitamin C[c] (μmol/L)
Education[1]				
Illiterate	24.0 (48)	3.36 ± 2.38	0.79 ± 0.75	26.09 ± 13.76
Primary	36.5 (73)	4.72 ± 4.27	0.91 ± 0.72	26.83 ± 17.69
Secondary	17.5 (35)	4.58 ± 4.44	1.03 ± 0.68	22.29 ± 15.05
>Secondary	22.0 (44)	4.92 ± 4.44	1.05 ± 0.83	22.59 ± 14.81
Occupation[2]				
Business	22.0 (44)	5.25 ± 4.89	1.10 ± 0.71	24.29 ± 15.91
Labor	24.0 (48)	4.03 ± 3.71	0.86 ± 0.71	26.79 ± 18.46
Rickshaw puller	19.0 (38)	4.70 ± 4.59	0.75 ± 0.64	24.23 ± 15.37
Service	24.0 (48)	4.22 ± 3.61	0.93 ± 0.80	26.11 ± 14.17
Others	11.0 (22)	3.51 ± 2.17	1.10 ± 0.81	24.70 ± 13.39
Income[3] (M) US$				
40–60	48.5 (97)	4.10 ± 3.69	0.89 ± 0.74*	24.79 ± 16.87
61–80	41.5 (83)	4.48 ± 4.19	0.90 ± 0.79*	25.23 ± 14.88
>80	10.0 (20)	5.68 ± 4.80	1.32 ± 0.78*	28.69 ± 13.32
Age (month)[4]				
6–24	38.0 (76)	4.04 ± 3.18*	0.93 ± 0.86	28.43 ± 16.68*
25–36	20.0 (40)	6.01 ± 5.54*	0.79 ± 0.74	27.25 ± 14.72*
37–48	18.5 (37)	4.17 ± 4.00*	1.02 ± 0.73	20.53 ± 16.61*
49–59	23.5 (47)	3.86 ± 2.52*	0.99 ± 0.67	22.59 ± 12.98*
Housing status[5]				
Building	18.5 (37)	5.85 ± 5.19*	1.02 ± 0.77	21.49 ± 11.64
Tin shed	34.0 (68)	4.42 ± 3.71*	1.03 ± 0.72	25.74 ± 16.84
Kacha	47.5 (95)	3.85 ± 3.62*	0.83 ± 0.80	26.60 ± 16.15
Z-score[6]				
Height for age[(i)]				
−2.00 and below	37.0 (74)	4.33 ± 4.16	0.80 ± 0.73*	23.20 ± 15.58
above −2.00	63.0 (126)	4.46 ± 3.97	1.01 ± 0.79*	27.31 ± 15.64
Weight for age[(ii)]				
−2.00 and below	69.0 (138)	4.47 ± 4.15	0.93 ± 0.76	25.72 ± 16.35
above −2.00	31.0 (62)	4.30 ± 3.78	0.95 ± 0.80	25.15 ± 15.38
Weight for height[(iii)]				
−2.00 and below	47.5 (95)	4.32 ± 4.22	0.95 ± 0.75	25.50 ± 16.32*
above −2.00	52.5 (105)	4.51 ± 3.86	0.92 ± 0.80	25.06 ± 14.37*

[1a]$F(3, 196) = 1.48$, $p = 0.21$; [1b]$F(3, 196) = 1.09$, $p = 0.35$; [1c]$F(3, 196) = 0.72$, $p = 0.53$; [2a]$F(4, 195) = 0.93$, $p = 0.44$; [2b]$F(4, 195) = 1.42$, $p = 0.22$; [2c]$F(4, 195) = 0.23$, $p = 0.92$; [3a]$F(2, 197) = 1.28$, $p = 0.27$; [3b]$F(2, 197) = 2.80$, $p = 0.05$; [3c]$F(2, 197) = 0.51$, $p = 0.60$; [4a]$F(3, 196) = 2.70$, $p = 0.04$; [4b]$F(3, 196) = 0.70$, $p = 0.54$; [4c]$F(3, 196) = 2.89$, $p = 0.03$; [5a]$F(2, 197) = 3.35$, $p = 0.03$; [5b]$F(2, 197) = 1.54$, $p = 0.21$; [5c]$F(2, 197) = 1.44$, $p = 0.23$; [6a(i)]$F(1, 198) = 0.05$, $p = 0.82$; [6b(i)]$F(1, 197) = 3.52$, $p = 0.05$;[6c(i)]$F(1, 197) = 0.06$, $p = 0.80$; [6a(ii)]$F(1, 198) = 0.07$, $p = 0.78$; [6b(ii)]$F(1, 198) = 0.04$, $p = 0.83$;[6c(ii)]$F(1, 198) = 0.03$, $p = 0.85$; [6a(iii)]$F(1, 198) = 0.11$, $p = 0.73$; [6b(iii)]$F(1, 198) = 0.08$, $p = 0.77$; [6c(iii)]$F(1, 198) = 3.45$, $p = 0.05$.
*$p < 0.05$.

$p = 0.05$). Serum vitamin C level was also shown to be significantly high in those ARI children whose weight-for-height was –2 SD and below (Z-score) ($F(1, 198) = 3.45$, $p = 0.05$).

Discussion

ARI is one of the leading causes of morbidity and mortality among children in the developing world.[44] Prevention and reduction of this mortality rate is a worldwide public health priority, but its referral system to hospitals for case management is poor.[45] The prevalent malnutrition is an associated cause of death in about 30%–45% of ARI patients.[46] Many of these deaths could be prevented by early diagnosis and appropriate antimicrobial therapy. Unfortunately, the widespread, often unnecessary, use of antimicrobials has resulted in the emergence of drug-resistant organisms contributing to an already high ARI-related mortality. To combat this huge number of deaths from ARI, a thorough careful history, clinical examination, proper investigation, and case management are of utmost importance. Therefore, to address this public health issue given clinical management, this study has attempted to an extensive investigation into the immunonutritional profile of the ARI children encompassing their socioeconomic and healthcare facilities.

Analysis of serum vitamins A, C, and E indicated that there had been a significant decrease in the concentrations of these antioxidant vitamins in ARI children as compared to that of the non-ARI cohort controls. The results indicate that the ARI children had been suffering from deficiencies of multiple antioxidant vitamins. Deficiencies of immunoregulating antioxidant vitamins in infections are well evidenced.[29,38] This particular outcome might be associated with decreased food intake, impaired nutrient absorption causing direct nutrient loss, increased metabolic requirements or catabolic loss, and impaired utilization by infections.[47] Vaccination with DPT and Polio did not give significant correlation with vitamin E, but BCG and measles vaccination showed that the ARI children, who are immunized with BCG, measles, and are breastfed, have higher serum level of vitamin A and E, and may be less likely to come across ARI incidence. In addition, proper breastfeeding is one of the key factors in early life nutrition among children and adolescents. It shows several beneficial effects on physical and cardiorespiratory fitness.[48]

In investigating the effect of socioeconomic and anthropometric factors on the vitamin level, income and housing status of the parents of ARI children had a significant correlation with vitamin A and E. The variables were positively correlated with age for vitamin A and C levels, stunting with vitamin A level and wasting with vitamin C level. Healthcare facilities, as well as socioeconomic factors of the ARI children, apparently influenced the level of these vitamins. Moreover, antioxidant vitamins and other nutrients may affect oxidative stress and immunity by interacting with each other when given combinedly. The combined supplementation of vitamin E and omega-3 fatty acids will increase the levels of total antioxidant capacity (TAC).[49] Vitamin D supplementation increases the serum levels of TAC, whereas decreases serum malondialdehyde levels.[50] In the present state of knowledge, no studies correlating the effect of immunonutritional profile together with socioeconomic and anthropometric factors on the antioxidant vitamin level of ARI-affected children in Bangladesh have been reported.

Limitations of the study

Although the research has attempted to be comprehensive, several limitations exist in this study. It would be better if we could evaluate the dietary intake and the quantity of antioxidants in the diet of participating children. This is considered a major limitation of this study. Besides, we did not measure the daily physical activities that effect the metabolism of vitamins in the body. Also, we did not detect the status of some other micro- and macronutrients, such as zinc, omega-3 fatty acids, vitamin D, copper, iron, and selenium, involved in the immunity. Only patients with microbiologically confirmed infections along with fast breathing and lower chest wall indrawing were included, while asymptomatic carriers were excluded in our analysis, which may have resulted in an underestimation of the true prevalence of the disease.

Conclusion

The study provides a wealth of information and allows exploring patterns related to ARI susceptibility among young children of Bangladesh in much greater detail than has been possible in preceding research. It has been found that poor socioeconomic conditions as well as housing patterns, proper vaccination, and multiple immunonutritional deficiencies are the significant factors of ARI in children and make them extremely prone to ARI. Immunonutritional deficiencies, in turn, induce increased susceptibility to ARI. These findings on the lifestyle and health variables and their relationships to ARI symptoms have thus been able to advance our knowledge. This will allow scholars and policymakers to evaluate the potential effectiveness of current undertakings aimed at refining public policy regarding ARI among young children. A significant reduction in the mortality rate can be achieved by implementing policies that embrace making available basic housing standards, enhancing the nutritional quality of diet, as well as improving immunization outreach program.

Author contributions

M.M.K., M.A., and S.N.I. conceived, designed, conducted, and analyzed the experiment. F.A. and M.R.I. collected the sample, analyzed the experiment, performed statistical analyses, wrote, and revised the manuscript. M.M.K. diagnosed and evaluated the study participants. M.A. and S.N.I. supervised the whole work and gave important intellectual content in the manuscript. All authors read and approved the final manuscript.

Ethical approval

The study was approved by the Ethical Review Committee of the Department of Pediatrics, Dhaka Medical College and Hospital, Dhaka, Bangladesh. All steps of these investigations were conducted as per the guideline declared by the Declaration of Helsinki.

Informed consent to participate

The aim of this study was briefly explained to each participant and written consent was taken from each of them who willingly participated in this study.

Informed consent to publish

All study participants or their primary caregivers acknowledged that anonymous data would be published in journal articles.

Informed consent

Legal protectors of all study participants were well briefed about the objective of the study and they signed informed consent. The written consent of the related was obtained from the primary care-giver if independent thinking capacity of any patient was suspected.

ORCID iD

Md. Rabiul Islam ![iD] https://orcid.org/0000-0003-2820-3144

Availability of data and materials

Data supporting our findings are available from the corresponding author on reasonable request.

Supplemental material

Supplemental material for this article is available online.

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