Original Article

Battling the Invisible Threat: Unraveling the Link between Acute Respiratory Bacterial Infections and Malnutrition in Children under Five

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Abstract

Objectives: This study determined the percent positivity of acute respiratory bacterial infections and their association with malnutrition in children under 5. Acute respiratory infections (ARIs) cause 6% of all diseases worldwide, with bacterial pneumonia being the leading cause of child mortality. Malnutrition accounts for 56% of childhood mortality worldwide, when combined with ARIs. **Materials and Methods:** This study included 185 hospitalized children under 5 diagnosed with ARIs. The nasal swabs were collected for bacterial isolation and analyzed using nutrient and blood agar and by Gram's staining. The bacterial pathogens were purified on Mannitol salt agar, chocolate agar, and MacConkey agar and identified using specific biochemical tests. Children's height and weight were compared with standards to assess their nutritional status. The data were statistically analyzed for percent positivity and Chi-square test. **Results:** The positive samples were collected from Allied Hospital (38.3%), Children Hospital (9.1%), and Faisal Hospital (11.8%). ARIs were categorized as mild pneumonia (35), moderate pneumonia (28), severe pneumonia (19), and no pneumonia/cold and cough (103). Among isolated bacteria, *Staphylococcus aureus* was the most prevalent bacterial species (23.2%), followed by *Klebsiella pneumoniae* (21.6%), *Pseudomonas aeruginosa* (7.57%), and *Streptococcus pneumoniae* (7.02%). Children with 24% stunted, 19% wasted, 23% underweight, and 34% having normal nutritional status were observed. Chi-square test ($P = 0.007$) showed significant results. **Conclusion:** It was concluded that there is a positive correlation between malnutrition and acute respiratory bacterial infections, as 66% of malnourished children were observed suffering from ARIs.

Keywords: Acute respiratory infections, association, bacterial infections, children, Klebsiella, malnutrition

Introduction

Acute respiratory infections (ARIs) are the most commonly reported diseases in children, especially those under 5, due to their developing immune systems and limited healthcare access.[1] ARIs normally cause difficulty in breathing and include infections of the upper and lower respiratory tracts. The most common infection among young children is an upper respiratory infection, with rare pneumatic symptoms.[2] Pneumonia is the most common cause of mortality in children with ARIs, and bacterial infections usually result in severe pneumonia.[3] Forty-eight out of every 1000 children under 5 die from ARIs in South Asia, including Pakistan.[4] ARIs have been linked to an unhygienic environment, inadequate sanitation, immunization deficiencies, malnourishment, and crowded living conditions.[5]

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It has long been known that the most common location of infections is the respiratory system, and most common among them are bacterial respiratory infections, considering the potential for antibiotic resistance for some bacterial strains.[6] The three most common bacterial pathogens are *Streptococcus pneumoniae (29.9%), Klebsiella pneumoniae (15.8%),*

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and *Mycoplasma pneumoniae* (18.6%).[7] *S. pneumoniae*, a Gram-positive bacterium, is a common cause of respiratory infections, particularly in young children and individuals with underlying medical conditions.[8] *Hemophilus influenzae* is a Gram-negative bacterium that frequently colonizes and infects the human respiratory tract, but its prevalence has decreased due to routine vaccination.[9] *K. pneumoniae*, another opportunistic bacterium, can cause serious infections, particularly in the lungs, and may lead to death, especially in patients on ventilators.[10] *Pseudomonas aeruginosa* is a nosocomial bacterium that can cause severe infections in hospitalized and immunosuppressed patients.[11]

The result of persistently inadequate nutrition, especially during a child's first 1000 days of life, is malnutrition. Millions of children worldwide suffer from malnutrition, which can cause different health issues, including ARIs. There are an estimated 155 million stunted children, 17 million severely wasted children, and 52 million wasted children worldwide.[12] Reducing malnutrition is essential as 2.6 million children die each year due to malnutrition.[13] Malnourished children are more likely to reside in rural areas of underdeveloped countries. Malnutrition is a prevalent issue in Pakistan, with 40% of children under five being stunted, 17.7% wasting, and 28.9% underweight (Pakistan's National Nutrition Survey 2018).

A growing number of germs are becoming resistant to drugs, making ARIs a global concern, and Pakistan is particularly affected by this, given the country has a high rate of malnutrition.[14] Bacterial respiratory infections are both common and inadequately investigated despite their widespread occurrence. This study aims to determine the prevalence and percentage of positive respiratory bacterial infections in children under 5, as well as the relationship between acute respiratory bacterial infections and undernourishment in young children.

Materials and Methods

Sample processing

Ethical approval was obtained from the Institutional Biosafety and Bio-Ethics Committee (IBC), University of Agriculture Faisalabad, and the respective ethical committees of Allied Hospital Faisalabad, Children Hospital Faisalabad, and Faisal Hospital Faisalabad. Samples were collected from children under 5 years of age diagnosed with respiratory infections caused by bacteria and children with chronic lung disorders and comorbidities. A total of 185 children hospitalized with ARIs participated in this study. With a 95% confidence level, the expected prevalence of ARIs among children under 5 years in Pakistan is 14%; the sample size was determined using the formula.[15] To choose the study participants, a simple random selection technique was used.

$$n = Z^2 P(1 - P)/d^2$$

$$n = (1.96)^2 \times 0.14(1 - 0.14)/0.0025$$

$$n = 185$$

Nutritional status

Anthropometric measurements of all the patients were taken, i.e., height and weight for nutritional assessment according to their age and gender. The nutritional status of every child was categorized according to the Z-scores. A child was considered "Stunted" when he/she has a height for age z-score below-2z, "Wasted" when he/she has a weight for height z-score below-2z, and "Underweight" when he/she has weight for age z-score below-2z, respectively, concluded from the World Health Organization (WHO) growth charts.

Clinical manifestation of acute respiratory infections

Samples were chosen based on their symptoms and diagnosis. Any cough lasting <2 weeks, regardless of fever, was classified as an ARI. According to WHO guidelines, ARI cases were categorized as having mild pneumonia, moderate pneumonia, severe pneumonia, or no pneumonia based on the presence of colds, coughs, fever, tachypnea, and clinical consequences [Figure 1].

Data on a range of socioeconomic, clinical, and demographic factors were collected to help control for possible confounding variables. These included the children's age and gender, their parents' education level, any existing health conditions, the family's monthly income, and their immunization status based on vaccination records. Clinical information was also gathered, such as how long each child stayed in the hospital and how many episodes of ARI they had experienced in the previous 6 months. By taking this comprehensive approach, the study aimed to more accurately assess the link between nutritional status and the risk of developing ARI.

Standardization of bacteria

Microorganisms were isolated from nasal swabs of patients with ARI. Normal saline was added for 10–20 min to the sample swabs for enrichment, and the samples were cultured on agar plates. For 24–48 h, the bacteria-inoculated plates were incubated at 37°C. Samples were inoculated in blood and nutrient agar for the growth enrichment of bacteria. After culturing, the colonies were processed for Gram's staining to study morphology.

Selective plating

To isolate bacteria, the samples were purified on different agar media supplemented with MacConkey, chocolate, and Mannitol salt agar. The pink colonies from MacConkey, white colonies from chocolate agar, and yellow colonies from MSA

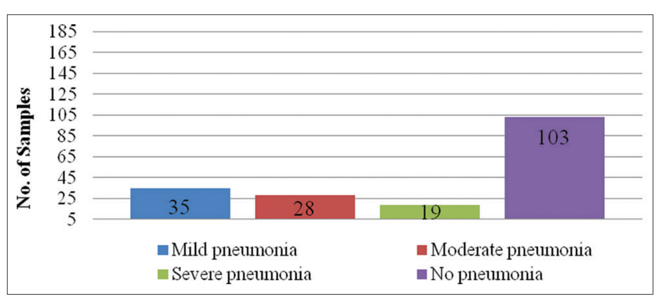

Figure 1: Representative graph showing disease severity of all the samples collected through Performa from children below 5 years

were selected for the pure culture as shown in Figures 2-4, respectively.

Biochemical tests

The bacterial pathogens were identified using specific tests such as the catalase test, oxidase test, inulin fermentation test, optochin sensitivity test, citrate utilization, methyl-red test, sugar fermentation test, and urease test. The analytical profile index was assessed based on their catalase and oxidase production, citrate utilization, and carbohydrate fermentation [Figures 5 and 6].

Statistical analysis

The data were analyzed by percent positivity, and a Chi-square test was applied to identify the relationship between malnutrition and acute respiratory bacterial infections. $P < 0.05$ was considered significant.

Results

A total of 185 children <5 years of age having ARIs from different hospitals in Faisalabad were enrolled in this study.

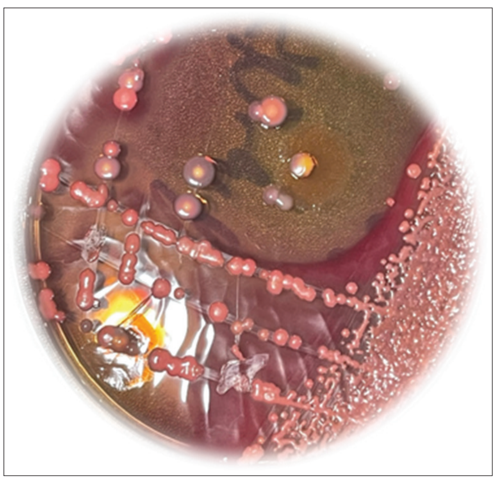

Figure 2: Representative figure showing growth of *Klebsiella pneumoniae* on MacConkey agar isolated through nasal swabs of children below 5 years

Figure 4: Representative figure showing growth of *Staphylococcus aureus* on Mannitol salt agar isolated through nasal swabs of children below 5 years

The nasal swabs of children having ARIs were collected to isolate microorganisms. Out of 185 samples, 35 patients with mild pneumonia, 28 with moderate pneumonia, 19 with severe pneumonia, and 103 patients with no pneumonia, having only symptoms like cough, etc., were found. It was observed that 123 (66%) children were malnourished, and 62 (34%) of them were normal [Figure 7]. A total of 45 (24%) children were stunted, out of which 6 had mild pneumonia, 8 had moderate pneumonia, 10 children had severe pneumonia, and 21 had no pneumonia. Thirty-six (19%) children were wasted, out of which 8 had mild pneumonia, 9 had moderate pneumonia, 4 children had severe pneumonia, and 15 had no pneumonia. Fourty-two (23%) children were underweight, out of which 7 had mild pneumonia, 5 had moderate pneumonia, 3 children had severe pneumonia, and 27 had no pneumonia [Table 1]. Nasal samples were collected from 185 confirmed ARI patients from different hospitals in Faisalabad. Among 185 collected samples, 110 were found positive for nutrient and blood agar. Out of 110 positive colonies, 43 (23.2%) isolates of *Staphylococcus aureus* were identified through the selective plating on MSA and biochemical tests, i.e., catalase and oxidase test, 13 (7.02%) isolates were identified as *S. pneumoniae* through tests such as optochin sensitivity test and inulin fermentation test, 40 (21.06%) isolates of *K. pneumoniae* were identified through selective plating on MacConkey agar and analytical profile index and 14 (7.57%) isolates of *P. aeruginosa* were identified

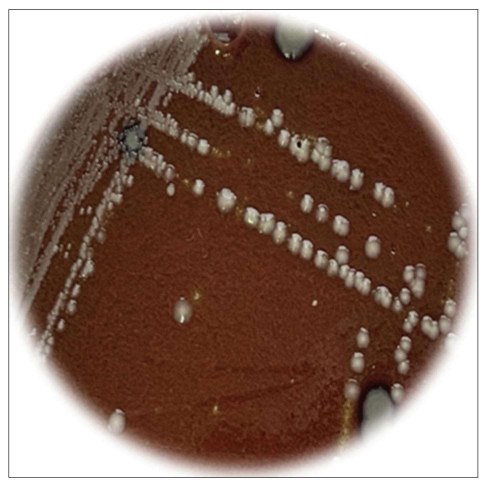

Figure 3: Representative figure showing growth of *Streptococcus pneumoniae* on chocolate agar isolated through nasal swabs of children below 5 years

Figure 5: Representative figure showing analytic profile index performed for *Klebsiella pneumoniae* isolated through nasal swabs of children below 5 years

Table 1: Representative table of malnutrition status of all the samples collected from different hospitals in Faisalabad

Hospitalized with ARIs	Number of samples	Stunted	Wasted	Under-weight	Normal
Mild pneumonia	35	6	8	7	14
Moderate pneumonia	28	8	9	5	6
Severe pneumonia	19	10	4	3	2
Cough and cold	103	21	15	27	40
Total	185	45	36	42	62

ARIs: Acute respiratory infections

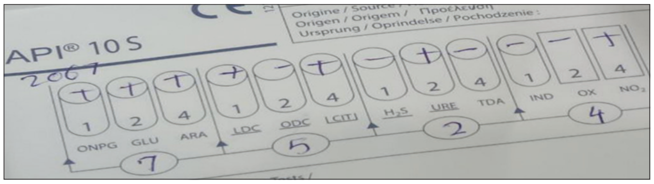

Figure 6: Representative figure showing resulting value of the API performed for *Klebsiella pneumoniae* isolated through nasal swabs of children below 5 years

through biochemical tests such as citrate and carbohydrate utilization, urease, and methyl red test [Table 2]. χ^2 results were χ^2 (9, n = 185) =22.863, P = 0.007, with a confidence interval of 95% which indicated that the results are significant. H_o was rejected, and a significant association between ARIs and malnutrition was found [Table 3].

The analysis considered a range of demographic, clinical, and socioeconomic factors to better understand how they relate to the risk of ARI in both well-nourished and malnourished children. These factors included age, gender, vaccination status as an indicator of immune health, parental education, and monthly household income. Clinical information was also evaluated, such as how many ARI episodes the children had in the past 6 months, how long they stayed in the hospital, and whether they had other existing health problems.

The results showed significant differences between well-nourished and malnourished children across several of these areas, especially in vaccination coverage, socioeconomic conditions, and past ARI history [Figure 8]. Overall, the findings point to a higher vulnerability to respiratory infections among malnourished children.

Discussion

ARIs are the most commonly reported infections among children worldwide. According to the WHO estimates, there were 42 million cases of ARIs in children under the age of five, resulting in an estimated 630,000 deaths.[16] The underdeveloped immune systems of young children, coupled with limited access to healthcare, increase their susceptibility to ARIs. Developing countries like Pakistan are disproportionately affected by ARIs because of indoor air pollution and malnutrition. This study is a nonrandomized cross-sectional investigation that included 185 hospitalized pediatric patients under 5 from numerous Faisalabad hospitals. The study observed the presence of several bacterial

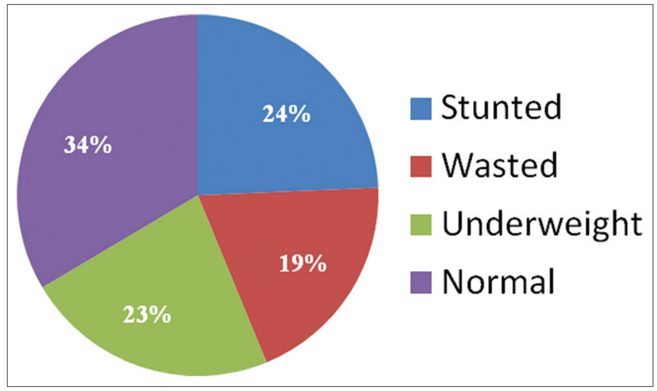

Figure 7: Representative chart showing nutrition status of children with ARIs below 5 years of age

pathogens among children suffering from ARIs. *S. aureus*, *S. pneumoniae, K. pneumoniae,* and *P. aeruginosa* were identified, accounting for 23.2%, 7.02%, 21.6%, and 7.57% of the cases, respectively, whereas according to Asghar *et al. S. aureus*, *S. pyogenes, S. pneumoniae, H. infuenzae,* and *K. pneumoniae* are the most prevalent ones known to cause ARIs in children. *S. pneumoniae*, *S. aureus*, *Mycobacterium tuberculosis*, *H. influenzae,* and *P. aeruginosa* were prevalent in most ARI cases.[17] These findings indicate that these bacteria are significant contributors to ARIs among children.

The study also evaluated the nutritional status of the children and found that out of 185 children, 24% were stunted, 19% were wasted, and 23% were underweight, whereas around the world, there are 155 million children who are stunted, 52 million who are wasted, and 17 million who are severely wasted.[12] Results of a national survey conducted in Pakistan (2018) indicated that 40% of children under 5 years of age were stunted, 17.7% were wasted, and 28.9% underweight. According to another study children under the age of five, there were 45.9% stunted children, 17.1% wasting children, and 35.4% underweight children.[18] These indicators reflect different aspects of malnutrition, with stunting representing chronic malnutrition, wasting indicating acute malnutrition, and underweight capturing a combination of both. In combination with an infection, malnutrition results in 56% of all deaths in children worldwide.[19] Indonesia holds the highest ARI rates with a predominance of 25% and nutritional morbidity of 14.9%.[20] In the Z-test, a statistically significant value of P = 0.007 was observed in this research, indicating a clear association between special bacterial infection and

Table 2: Representative table of samples collected from different hospitals, positive bacterial samples, and their percent positivity rates

Source of sample (children >5 years)	Total number of samples	*Staphylococcus aureus*	*Streptococcus pneumoniae*	*Klebsiella pneumoniae*	*Pseudomonas aeruginosa*
		Percent positivity			
Allied hospital	90	25.6	10	35.6	7.78
Children hospital	50	22	2	6	4
Faisal hospital	45	20	6.6	11.12	11.12
Total	185	23.2	7.02	21.6	7.57

Table 3: Representative table of Chi-square test performed to access strength of association between acute respiratory infections and malnutrition

	df	Value	CI	Asymptomatic significance (two sided) *P*
Pearson-Chi square	9	22.863	95%	0.007

CI: Confidence interval

condition of nourishment of children. The outcomes suggest that children with some bacterial infections are likely to manifest signs of malnutrition than the ones who are not afflicted by the same.

The question of this connection is paramount to medical workers, since it provides the opportunity to build specific preventive and treatment measures. Preventive approaches have the potential to make a critical contribution to lessening the double scourge of bacterial infections and undernutrition in children. Essential care entails hand hygiene reinforcement, early immunization against the common bacterial infections, adoption of infection control measures at both the community and hospital levels, and adoption of proper diets. It is of equal importance to consider caregiver education programs that would enhance the feeding process and interventions that would alleviate the obstacles to the availability of balanced diets. Nutrition programs carried out in the community, food supplementation or supplementation programs, and awareness are some agencies that can supplement these measures and encourage healthy growth and development in children. The results of the study support the close relationship between the nutritional status and the incidence of ARI developing the possibility in children under the age of 5 years. ARI and its complications were much more likely to occur in malnourished children as compared to the well-nourished children. This vulnerability is influenced by diverse factors which are a product of clinical, demographic, and socioeconomic correlates. One of the determinants was the age. Compared to well-nourished children (16.1%), a larger proportion of malnourished patients were found to be infants aged 0–12 (35.8%). This implies that with their poor developmental level, infants are unproportionately hit by poor nutrition, leaving the immune system weakened. Children in the age group of 4–5 years, in comparison, were being more often represented in the group of well-nourished children (41.9%), as they improved their immunity and resilience due to their proper nutrition level and age advancement. Another valuable factor that affected the ARI incidence was the immunization status. Fully immunized children were dominant among the well-nourished children (79.0%) in comparison with completely inoculated children who were only half (51.2%) among the malnourished children. This gap highlights differences in healthcare access and awareness, with vaccination providing critical protection against infections. Lack of complete immunization leaves malnourished children doubly disadvantaged, nutritionally weakened, and immunologically unprotected. Parental education also strongly influenced outcomes. Nearly half of the malnourished children (45.5%) had illiterate parents, whereas only 29.0% of well-nourished children came from such backgrounds. In contrast, parents of well-nourished children often had secondary or higher education, equipping them with better knowledge of child care practices, including nutrition, vaccination, and hygiene.

Household income was equally influential. Over half of the malnourished children belonged to families with monthly incomes below 25,000 PKR, whereas well-nourished children more frequently came from economically stable households. Poverty restricts access to nutritious food and healthcare, amplifying the risks of both malnutrition and infection. Clinically, malnourished children not only experienced more frequent ARI episodes but also showed slower recovery. Almost half (48.8%) of malnourished children had at least one ARI episode in the last 6 months, compared to only 19.4% among well-nourished children.[21] Hospitalization periods also differed significantly, with only 35.0% of malnourished children recovering within 3 days compared to 56.5% of well-nourished children. This prolonged recovery is consistent with impaired immune responses in malnourished individuals. In conclusion, the evidence clearly establishes that malnutrition exacerbates both the risk and severity of ARI in young children, particularly when combined with socioeconomic disadvantages such as poverty, incomplete vaccination, and parental illiteracy. On the other hand, well-nourished children have fewer respiratory infections in addition to being quick to heal. It is also due to these findings that there is a strong necessity to have integrated child health programs by means of including nutritional interventions to ensure that the preventive care is given, providing a nonlocalized view regarding child health.[22]

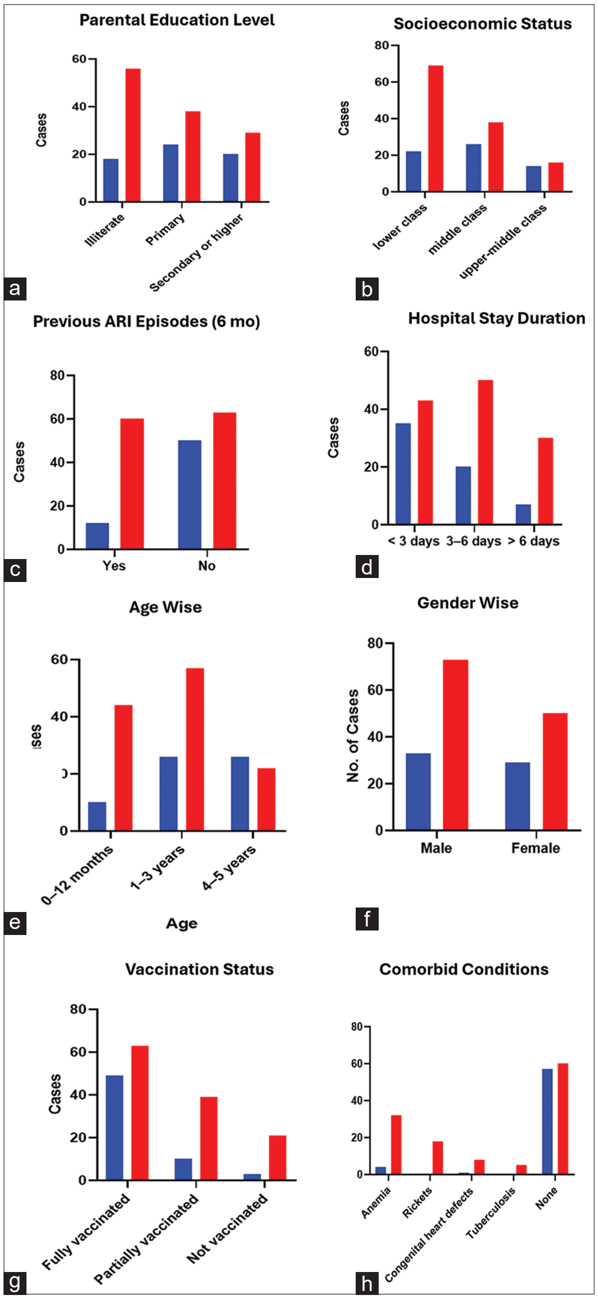

Figure 8: Comparative analysis of demographic, clinical, and socioeconomic factors associated with acute respiratory infections (ARI) in well-nourished and malnourished children. (a) Parental literacy status among well-nourished and malnourished children with ARI (illiterate, primary, secondary, or higher). (b) Socioeconomic condition among well-nourished and malnourished children affected by ARI. (c) Number of well-nourished and malnourished children with or without prior ARI episodes in the last 6 months. (d) Duration of hospital stay for well-nourished and malnourished children with ARI (<3 days, 3–6 days, >6 days). (e) Distribution of well-nourished and malnourished children with ARI by age categories (0–12 months, 1–3 years, 4–5 years). (f) Proportion of male and female well-nourished and malnourished children diagnosed with ARI. (g) Frequency of comorbid conditions among well-nourished and malnourished ARI cases (anemia, rickets, congenital heart defects, tuberculosis, none). (h) Categories of ARI cases among well-nourished and malnourished children by vaccination status (fully vaccinated, partially vaccinated, unvaccinated)

Conclusion

This study underlines the close relationship between ARI and malnutrition among under 5 years of aged children. Malnutrition compromises the immune system, thus exposing one to bacteria, including *S. aureus* and *K. pneumoniae*. Recurrent infections negatively affect undernutrition since they compromise the nutrient absorption and increase the energy needs, creating the vicious cycle of disease and malnutrition. Among the risk factors that drive this cycle, there are younger age, inadequate vaccination, illiteracy of parents, and a low household income. Malnourished children not only have a higher likelihood of recurrent episodes of ARIs but also had longer hospital morbidities, indicating that they are less resilient in nature and their immunity is low. An overall public health strategy is needed to break this cycle. Interventions that are nutrition-related must be combined with vaccines, campaigns about parental education, and social assistance to poor households. Routine nutritional status screening can be used in the context of pediatric healthcare to screen the child population early enough to take the preventative measures needed.

Simultaneously testing the effect of strengthening nutrition and preventative healthcare is the best approach in minimizing the occurrence of ARIs and enhancing the recovery of persons who contract the disease in resource-poor settings like in Faisalabad. Organized, community-based programs will be able to both provide children with proper nutrients and safeguard them against infections by causing infectious diseases, hence creating better child health and survival in general.

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Conflicts of interest

There are no conflicts of interest.

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