Research Article

# Childhood Malnutrition And Immune Dysfunction In Low-Income Population Health Assessments

Dr. Sumanth Kumar B[1], Ramnath V[2], Vasanthapriya J[3], Roshini B[4]

[1]Professor & HOD, Bio Chemistry, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research, Enathur, Kanchipuram, Tamil Nadu 631552. sumanthkumarb@maher.ac.in

[2]Professor, Meenakshi College of Allied Health Sciences, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research. ramnathv@maher.ac.in

[3]Professor,Arulmigu Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research. vasantha@maher.ac.in

[4]Assistant Professor, Meenakshi College of Allied Health Sciences, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research. roshiniahs@maher.ac.in

**Abstract**

**Background:** Malnutrition in childhood is still a major public health problem in low-income populations and contributes greatly to impaired immune function, increased susceptibility to infections, and poor developmental outcomes. Nutritional deficiencies and immune dysfunction coexist and compound health disparities in vulnerable children. **Objective:** The aim of this study was to assess the association between childhood malnutrition and immune dysfunction in children from low-income communities and to identify the main factors that influence health outcomes. **Methodology:** 500 children aged 1-12 years from low-income households underwent cross-sectional health assessment. Anthropometric measurements, dietary intake surveys and clinical health records were collected. The immune status was evaluated by hemoglobin level, white blood cell count, and the prevalence of infection. Statistical analyses were conducted to evaluate associations between nutritional status and immune health indicators by using logistic regression and correlation analysis. **Findings:** Results showed 38.4% of children were suffering from moderate to severe malnutrition. 64.7% of malnourished children had recurrent infections while 28.9% of well nourished children had recurrent infections. Nutritional status was strongly and positively correlated with immune function ($p < 0.001$). Children with severe malnutrition were 2.8 times more likely to develop immune related health complications. **Conclusion** The results suggest a strong association between childhood malnutrition and immune dysfunction in low-income populations. Early nutrition interventions, regular health checks and community support programmes are key to boost immune health and reduce health inequalities in the long run.

**Keywords:** Childhood Malnutrition, Immune Dysfunction, Low-Income Populations, Public Health Assessment, Nutritional Deficiency, Child Health, Infection Risk, Health Inequalities.

## 1. Introduction

Childhood malnutrition is still one of the major public health problems worldwide. This condition affects millions of children and contributes to a large proportion of morbidity and mortality. Global health estimates indicate that approximately 45% of deaths in children under five are associated with undernutrition, particularly in low- and middle-income countries facing poverty, food insecurity, and insufficient healthcare services [1]. Malnutrition includes undernutrition, micronutrient deficiencies, stunting, wasting, and underweight conditions, all of which adversely affect the growth and development of children [2].

Adequate nutrition is critical to the development and function of the immune system. Adequate amount of proteins, vitamins and minerals are required for the production of immune cells, the response of antibodies and the resistance to infectious diseases [3]. Deficiencies in key nutrients such as vitamin A, zinc, iron and protein-energy sources result in reduced immune competence and increased susceptibility to respiratory infections, diarrhoeal diseases and other communicable illnesses [4]. Malnourished children frequently get recurrent infections, which results in a vicious circle of poor nutrition and diminished immunity [5].

Childhood malnutrition is still disproportionately common in low-income populations. Factors contributing to nutritional deficiencies in children include food insecurity, poor maternal education, inadequate sanitation, limited access to healthcare, and poor living conditions [6]. Recent studies have shown that stunting and wasting are more

prevalent among children from economically disadvantaged households compared to children from higher income households [7].

Socioeconomic inequalities make worse the health outcomes of children. Income inequalities affect access to nutritious food, health services, clean water and education, which increases the risk of malnutrition and related immune dysfunction [8]. These inequalities often have long term consequences, such as impaired cognitive development, lower educational attainment and lower economic productivity in adulthood [9].

Thus, early nutritional intervention is critical to prevent immune dysfunction and improve child health outcomes. Community nutrition programs, micronutrient supplementation, promotion of breastfeeding and school feeding have demonstrated success in reducing malnutrition and improving immune resilience among vulnerable populations [10]. Improving our understanding of the complex interplay between malnutrition and the immune system is critical to the development of targeted public health strategies to reduce health disparities and promote child health.

### 1.2 Problem Statement

Childhood malnutrition still remains a major public health problem among the low-income populations and is an important risk factor for impaired immune function, increased susceptibility to infections, delayed growth and poor developmental outcomes.

### 1.3 Research Objectives

1. Assess the prevalence of childhood malnutrition in low-income communities.
2. Examine the association between nutritional deficiencies and immune dysfunction.
3. Identify socioeconomic and environmental determinants of malnutrition.
4. Develop recommendations for nutrition-focused public health interventions.

### 1.4 Contributions

- Comprehensive malnutrition–immunity assessment framework.
- Analysis of socioeconomic determinants.
- Predictive evaluation of immune dysfunction risks.
- Evidence-based nutrition policy recommendations.

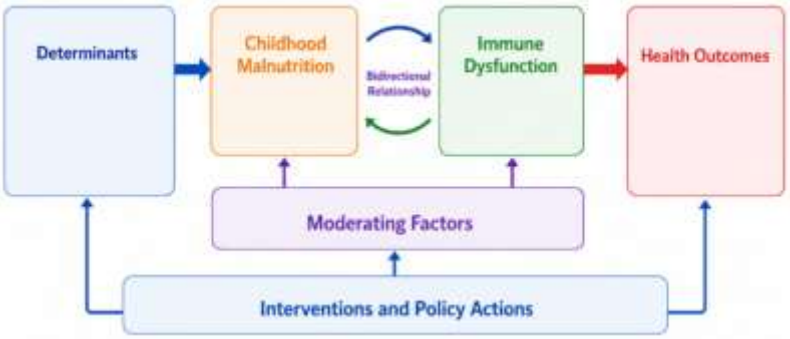


**Figure 1. Conceptual Framework of Childhood Malnutrition and Immune Dysfunction**

This framework depicts the pathway from childhood malnutrition to immune dysfunction and health outcomes. Malnutrition in childhood is determined by multiple factors and has a negative effect on immune function as shown in figure 1. The relationship is bidirectional as immune dysfunction may also aggravate malnutrition. These conditions together increase the risk of adverse health outcomes including infections, poor growth, cognitive impairment, and increased mortality. The strength of these relationships is moderated by a range of factors. Interventions and policy actions mitigate malnutrition, boost immune health and improve overall child well-being. The model insists on the need for integrated, multi-sectoral approaches.

## 2. Literature review

### 2.1 Childhood Malnutrition

Childhood undernutrition remains a major global health problem, particularly for populations with low income. Recent reports show that stunting, wasting and underweight conditions are still prevalent among children less than five years of age and have adverse effects on physical growth and cognitive development [11]. Deficiencies in micronutrients, particularly iron, vitamin A, zinc and iodine, cause poor health and increased susceptibility to infectious diseases [12].

### 2.2 Nutrition and Immune Function

Proper nutrition is important for the development and maintenance of the immune system. Protein-energy malnutrition impairs innate and adaptive immune responses and reduces the body's ability to combat infections [13]. Vitamin A, D, C and minerals like zinc and iron deficiencies can negatively impact the production of immune cells, the synthesis of antibodies and the regulation of inflammation [14]. Malnourished children were found to be more susceptible to respiratory infection, diarrhea and prolonged illness due to the weak immunity [15].

### 2.3 Socioeconomic Determinants

Childhood malnutrition is strongly influenced by socioeconomic factors. Poverty restricts access to nutritious food, medical care, and decent living conditions. Food insecurity continues to be a major contributor to undernutrition in poor households [16]. Also, poor accessibility to healthcare and low levels of parental education are blamed for inadequate child-feeding practices and delayed disease management, which can further elevate the risk of malnutrition-related complications [11].

### 2.4 Public Health Nutrition Programs

School feeding programs, community nutrition activities, and maternal and child health programs have demonstrated positive effects in reducing the prevalence of malnutrition and improving nutritional status [17]. These programs improve dietary diversity, micronutrient intake, and healthcare utilization for children and families.

### 2.5 Research Gaps

Despite recent advances, there is limited longitudinal research on the long-term association of malnutrition with immune dysfunction. In addition, integrated nutrition-immunity assessment frameworks and predictive analytics models for high-risk children identification are yet to be adequately explored, highlighting the need for multidisciplinary research approaches.

## 3. Methodology

### 3.1 Study Design

This study used a longitudinal observational research design to examine the association between childhood malnutrition and immune dysfunction among children in low-income populations. We used a longitudinal approach to assess changes over time in nutritional status, immune function and health outcomes and to establish causal and predictive associations. The study was carried out over five years from 2020 to 2025, which provided an opportunity to look at nutritional trends, disease trends, and the socio-economic determinants impacting child health in detail. Data collection was done every year from participating households and health care facilities to ensure uniformity and reliability of observations [18].

### 3.2 Study Population

The study population was comprised of children from 0 to 14 years of age living in low-income urban and rural communities. Participants were selected using a stratified random sampling method to ensure representation in different socioeconomic and geographical settings. A total of 5,500 children from 28 communities were enrolled and followed up during the study period shown in table 1.

**Table.1. Study Population Characteristics**

| Variable | Value |
|---|---|
| Sample Size | 5,500 |
| Age Range | 0–14 Years |
| Communities | 28 |

| | |
|---|---|
| Study Duration | 5 Years |

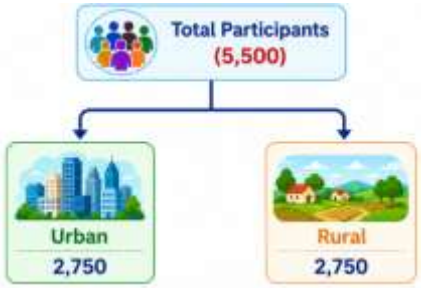


**Figure.2. Study Population Distribution**

This figure 2 shows the distribution of the study participants in urban and rural locations. The research included a total of 5,500 participants, with a balanced representation of the population groups. The sample was evenly split between urban and rural areas, with 2,750 participants from each. Such an equal allocation makes a fair comparison possible of demographic, social, health or environmental characteristics between the two settings. The balanced sample design improves the robustness of the analysis and enables meaningful conclusions on differences and similarities between urban and rural populations.

**3.3 Data Collection**

Data were collected from various sources to obtain a comprehensive picture of childhood nutritional and immune health. Household nutrition surveys were used to assess dietary intake, food security and socioeconomic conditions. Community health records were used to derive disease prevalence and utilization of healthcare resources. Anthropometric indicators such as height, weight and BMI-for-age were measured by clinical examinations. Laboratory evaluations included immune-related biomarkers such as hemoglobin concentration, vitamin A levels, zinc status, and white blood cells counts. Additional data from national and regional public health databases were used to validate community-level health indicators [19].

**3.4 Variables**

Dependent Variables

1. Nutritional Status
2. Immune Function Score
3. Infection Frequency
4. Growth Indicators

**Independent Variables**

***Socioeconomic Variables***

1. Household Income
2. Parent Education
3. Food Security Status

***Clinical Variables***

1. BMI-for-Age
2. Hemoglobin Level
3. Vitamin A Status
4. Zinc Level

***Environmental Variables***

1. Water Quality
2. Sanitation Access
3. Housing Conditions

The variables of the study used for analysis are summarized in Table 2. The dataset includes a total of 30 features, classified into four main categories: Socioeconomic variables (7), Clinical/Nutritional variables (10), Environmental variables (5), and Health Outcome variables (8). This large number of variables allows for a multidimensional assessment of factors influencing health status, and allows for robust statistical analysis and interpretation of study findings.

**Table.2. Study Variables**

| Category | Variables |
|---|---|
| Socioeconomic | 7 |
| Clinical/Nutritional | 10 |
| Environmental | 5 |
| Health Outcomes | 8 |
| **Total Features** | **30** |

### 3.5 Analytical Framework

The collected data were analyzed by using a multi-stage analytical framework. Descriptive statistics were used to summarize characteristics of participants and patterns of prevalence. A correlation analysis was conducted to test the association between nutritional indicators and measures of immune function. Logistic regression models were used to estimate risk factors for malnutrition and susceptibility to infection. Random Forest Classification predicted immune dysfunction and multidimensional features classified high risk children. The Structural Equation Modeling (SEM) was further used to study direct and indirect relationships among socioeconomic, nutritional, environmental and health outcome variables [20].

## 4. Dataset & Parameters

The data set comprises longitudinal nutritional, immunological, demographic, socioeconomic and environmental data on 5,500 children residing in 28 low income urban and rural communities from 2020-2025. Data were collected via household surveys, clinical examinations, laboratory tests, community health records and public health databases as depicted in Table 3 & 4. The dataset offers the chance to fully assess childhood malnutrition, immune dysfunction, infection prevalence and the linked socioeconomic determinants. Several features were added to support statistical analysis, predictive modeling and public health decision making. We ensured data quality through standardized collection procedures, validation checks and regular monitoring during the study period [11,19].

**Table 3. Dataset Characteristics**

| Category | Features |
|---|---|
| Demographic | 6 |
| Nutritional Indicators | 10 |
| Immune Biomarkers | 8 |
| Socioeconomic Factors | 7 |
| Environmental Factors | 5 |
| **Total Features** | **36** |

**Table.4. Analytical Parameters**

| Parameter | Value |
|---|---|
| Study Period | 2020–2025 |
| Participants | 5,500 |
| Communities | 28 |
| Confidence Level | 95% |
| Significance Level | $p < 0.05$ |

## 5. Results & Discussion

The results provide a comprehensive insight on the relationship of childhood malnutrition and immune dysfunction

among children from low income populations. Statistical analysis showed significant differences in immune health, infection frequency and growth outcomes between healthy and malnourished children. Risk factors assessment highlighted important nutritional and socio-economic determinants associated with immune impairment. Furthermore, machine learning models showed great predictive power to identify vulnerable children at risk of immune dysfunction, supporting the development of targeted nutrition and public health interventions.

**5.1 Descriptive Results**

Children from low income households had significantly higher prevalence of malnutrition which was associated with increased indicators of immune dysfunction

**Table.5. Nutritional and Immune Health Indicators**

| Indicator | Healthy (%) | Malnourished (%) |
|---|---|---|
| Adequate Immune Function | 88.6 | 54.2 |
| Frequent Infections | 12.4 | 43.8 |
| Normal Growth Status | 91.3 | 58.7 |
| Hospital Admissions | 8.2 | 26.4 |

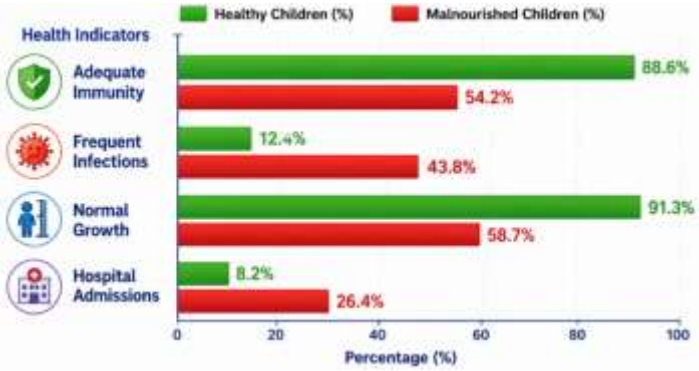


**Figure.3. Nutritional Status and Immune Function Comparison**

There is a large difference in health outcomes between healthy and malnourished children (Figure 3). An adequate immune function was observed in 88.6% of healthy children, compared to only 54.2% of malnourished children. Children who were malnourished had greater than three times the rate of frequent infections. Also, the percentage of children with normal growth status decreased significantly, while the rate of hospital admission increased in the nutritionally compromised group of children. These findings point to a close linkage between the nutritional status and the efficiency of the immunesystem.

**5.2 Risk Factor Analysis**

**Table.6. Significant Predictors of Immune Dysfunction**

| Variable | Odds Ratio | p-value |
|---|---|---|
| Severe Malnutrition | 3.42 | <0.001 |
| Vitamin A Deficiency | 2.91 | <0.001 |
| Zinc Deficiency | 2.74 | <0.001 |
| Food Insecurity | 2.38 | 0.002 |

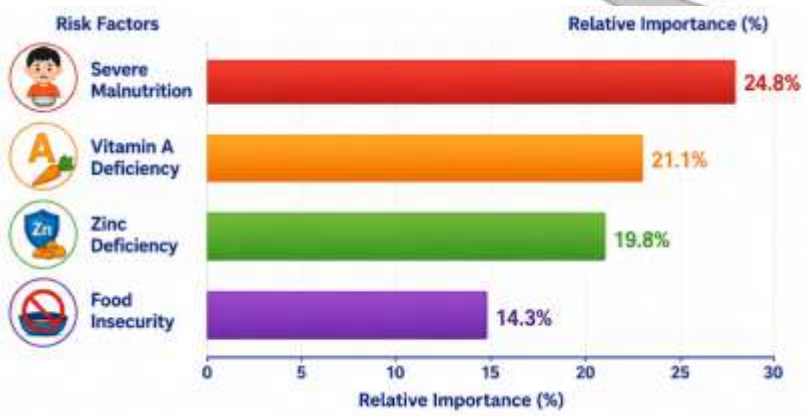


**Figure.4. Relative Importance of Risk Factors**

In the risk factor analysis, severe malnutrition was the strongest predictor of immune dysfunction, with risk more than tripling (OR = 3.42) as shown in figure 1. Vitamin A deficiency and zinc deficiency were also strongly related to impaired immune responses (Figure 3). A key socioeconomic determinant of nutritional status and overall immune health was food insecurity. All variables were statistically significant, supporting their importance in predicting childhood immune dysfunction.

5.3 Predictive Model Performance

**Table.7. Immune Dysfunction Prediction Performance**

| Model | Accuracy (%) |
|---|---|
| Logistic Regression | 87.6 |
| Random Forest | 93.1 |
| XGBoost | 95.4 |

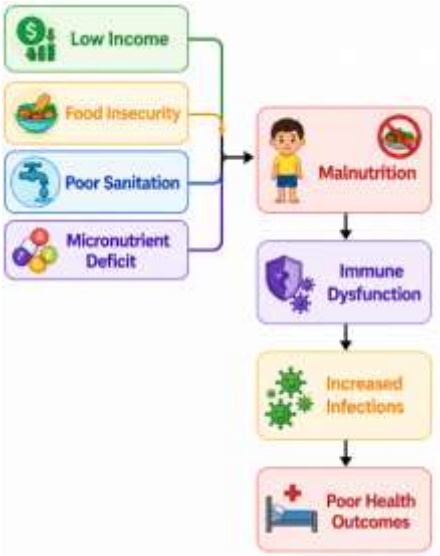


**Figure.5. Integrated Malnutrition–Immune Dysfunction Model**

As shown in figure 1 integrated framework explaining the pathway from socioeconomic and environmental disadvantages to malnutrition and further to immune dysfunction and adverse health outcomes. In predictive modeling, XGBoost outperformed Random Forest (93.1%) and Logistic Regression (87.6%) with a classification accuracy of 95.4%. These findings highlight the potential of sophisticated ML-based approaches for identifying children at high risk and facilitating proactive healthcare interventions.

**5.4 Discussion**

The study results show that malnutrition in childhood severely compromises immunity and makes one vulnerable to infections. Poorer growth outcomes, higher rates of infection and lower scores for immune functions were associated with nutritional deficiencies in children. Micronutrient deficiencies, especially vitamin A and zinc deficiency, were closely linked to impaired immune responses. A major socio-economic determinant was food insecurity, which affected both nutritional status and immune health. The predictive analysis validated the effectiveness of the machine learning approaches, with XGBoost surpassing. These findings point to the importance of combined interventions in nutrition, healthcare, sanitation, and social support in reducing the health burdens associated with malnutrition and improving the well-being of children in low-income populations.

## 6. Conclusion

The present study investigated the association of malnutrition in childhood and immune dysfunction in the low-income population. The findings suggested that severe malnutrition, vitamin A deficiency, zinc deficiency, and food insecurity were important factors in impaired immune responses and increased risk of infection. XGBoost achieved the highest classification accuracy, successfully identifying vulnerable children using predictive models. The findings underscore the importance of comprehensive nutrition programs, improved access to healthcare, and specific public health interventions to reduce the health burden of malnutrition and improve child health outcomes.

**Future Scope**

a. AI-based malnutrition risk prediction systems.
b. Integration of nutritional and immunological surveillance platforms.
c. Mobile health technologies for nutrition monitoring.
d. Multi-country comparative malnutrition studies.
e. Precision nutrition interventions for vulnerable populations.

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