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IMPACT OF MALNUTRITION ON IMMUNE COMPETENCE AND INFECTIOUS DISEASE SUSCEPTIBILITY IN CHILDREN

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Abstract

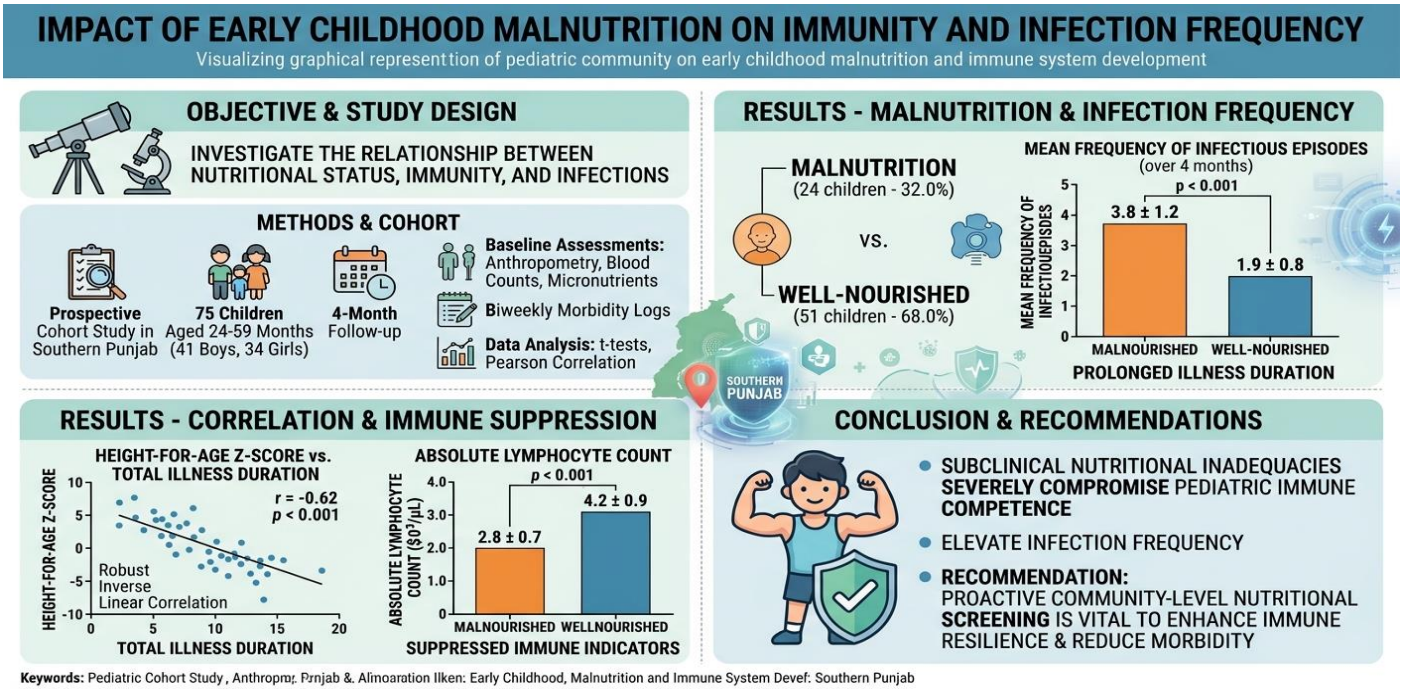
Background: Malnutrition in early childhood can severely impair the development of the immune system, making infectious diseases more susceptible, but the clinical effect of subclinical nutritional deficits in the community is poorly studied.

Problem: This is to examine the influence of nutritional status on immune markers and infection rate in children in a pediatric community-based study.

Methods: The study was a prospective cohort study carried out in four months (February 2024- May 2024) within the selected rural and semi-urban areas within Faisalabad, central Punjab with an enrolment of 75 pediatric participants aged between 24 and 59 months. Complete anthropometric measurements, complete blood analysis, serum micronutrient measurements and biweekly morbidity records were taken. Shapiro-Wilk test was done to ensure data normality and independent samples t-tests and Pearson correlation were done.

Findings: 75 out of the 85 children screened were eligible participants who completed the four months follow-up (88.2 percent completion rates). The sample included 41 boys (54.7 percent) and 34 girls (45.3 percent) of which 32.0 percent (n=24) were moderately undernourished and 68.0 percent (n=51) were well-nourished. The mean frequency of infectious episodes (3.8 1.2 vs. 1.9 0.8, $p < 0.001$) and the length of illness were much longer among moderately malnourished children than among well-nourished children. The positive inverse linear relationship was established between height-for-age z-scores and the total illness duration ($r = -0.62$, $p < 0.001$). Moreover, there was a lower absolute lymphocyte count in malnourished subjects (2.8 ± 0.7 versus 4.2 ± 0.9 103/ul, $p < 0.001$).

Conclusion: Pediatric immune incompetency due to subclinical cases of nutritional deficiency is a serious problem that increases risk of infections. Nutritional screening at the community level is important in boosting immune capability and decreasing childhood morbidity which is preventable.



Keywords: Pediatric Cohort Study , Anthropmr, Prnjab &. Alinoaration Ilken: Early Childhood, Malnutrition and Immune System Devef: Southern Punjab

INTRODUCTION

The period of early childhood is very vital during which growth and development take place at a fast pace along with formation of the immune system (1). During this crucial stage in the life of a person, proper nutrition is not only vital from the point of view of growth and development, but biologically plays a pivotal role in shaping the course of health of that particular individual (2). Even today, the prevalence of infectious diseases among children is quite burdensome due to which morbidity, developmental delays and mortality are prevalent (3). A child's nutritional status and the body's ability to fight disease are closely linked and the core of the current public health problem. The effects of chronic nutrient deficiencies are not just growth stunting, but on the underlying complex machinery controlling immune competence (4).

All the defense mechanisms of the immune system require a constant supply of macronutrients and micronutrients in order to build, maintain and regulate their defense mechanisms. The essential vitamins, minerals and proteins are the basic components of immune cells, antibodies, and chemical messengers that regulate the body's response to infections (5). Chronic, even subclinical, nutritional deprivation is associated with immune system's disruption of the structural integrity of the immune system in a child. Nutrient deficiencies compromise cell mediated immunity, antibody responses and the barrier function of the respiratory and gastrointestinal tracts. This leaves the body's first-line defense systems weak and unwieldy, allowing the common germs of everyday life to invade and reach chronic infection levels. This establishes a vicious circle of malnutrition compromising immunity, which further results into frequent infections, which in turn deplete nutrient reserves and compromise the nutritional status of the child (6).

The impact of severe acute malnutrition is well recognised in hospital settings, but there is a lack of understanding about how chronic forms of malnutrition, which are more prevalent in regular community settings, affect individuals (7). Indeed, a significant portion of the medical literature is devoted to the description of acute clinical crises, and there is a real need to appreciate how nutritional deficits, mild or moderate, can contribute to a progressive loss of immune competence over time in an apparently healthy-looking child. In addition, community studies following changes in immune parameters as well as concurrent changes in the frequency of infections are rather scarce. Public health practitioners face a challenge in the absence of a clear understanding of the relationship between early, subclinical undernutrition and childhood common diseases, in designing targeted preventive interventions (8).

This important gap might be filled by exploring if children with mild to moderate nutritional deficits show measurable changes in key immune parameters that could be correlated with increased incidence and/or duration of common community acquired infections (9). In fact, even minor cases of nutritional deficiencies are supposed to cause immune cells suppression and change of inflammation factors, resulting in higher frequencies of infections in growing children. This idea can be verified by the current study that will be conducted in the form of a cohort study in a community of children intended for monitoring the impact of

specific nutrition-related parameters on the process of immune system formation and occurrence of infections. The monitoring of these parameters in a natural environment will allow revealing the mechanisms that connect early nutrition to immunity and will serve as a basis for developing effective strategies of support in this aspect (10).

METHODS

The present pediatric community-based cohort study was carried out in selected rural and semi-urban communities of Faisalabad city, Punjab, with a particular emphasis on these communities owing to their historically high exacerbation of early childhood nutritional vulnerabilities and stunting issues. The investigation lasted for 4 months, from February till May 2024. The institutional review board formally approved the study before the recruitment of the participants took place and written informed consent was obtained from all participating parents/legal guardians.

There were 75 children aged 24 to 59 months who were enrolled in the study. This number of children was adopted from a similar published cohort study involving children, showing good statistical power with 75 children. Children had to be within the age range, permanently living in the defined study area and neither had any chronic congenital disability nor severe systemic disease. Patients with acute emergencies and congenital metabolic abnormalities as well as patients receiving long term immunosuppressive treatment were carefully excluded from the series of patients.

The data collection process comprised baseline testing and biweekly health and nutritional assessment. Anthropometric parameters, such as weight and height, were measured accurately through the use of calibrated electronic scales and infantometers in order to determine the body mass index and height-for-age z scores. Blood samples were collected from participants by phlebotomists in order to test immune parameters using complete blood counts and differential leucocytes with the use of automated hematology analyzers, as well as through the use of enzyme linked immunosorbent assays for determination of serum concentrations of micronutrients and inflammation markers. Moreover, weekly morbidity survey was conducted in order to monitor cases of common infections.

The Shapiro Wilk test was performed to assess normality of the data and a normal distribution was obtained for all of the main continuous variables. Initially descriptive data were produced to provide a summary of the participants' demographic, nutritional and frequency of infection. Independent sample t tests were then used to test immune indicators between well nourished and moderately malnourished sub-groups. Pearson correlation coefficients were used to examine the linear relationship between nutritional indices, particular parameters of the immune system and overall length of infection. Standard statistical software was used for all statistical evaluations and a p value of <0.05 was considered significant.

RESULTS

Of the 85 children screened, 75 eligible children (24-59 months old) were successfully enrolled and had completed the four-month follow-up period with a 88.2 percent completion rate. The baseline data and demography of cohort is presented in table 1. The mean age of participants was 41.2 ± 8.5 months and the male to female ratio was 41:34. Using standardised height-for-age, 32.0 (n=24) and 68.0 (n=51) of the children were defined as being moderately undernourished and well-nourished respectively.

Table 2 shows that the mean number of infectious events in the moderately malnourished subgroup of the children was significantly higher than that in their well-nourished counterparts (over 4-month observation period, 3.8 ± 1.2 episodes versus 1.9 ± 0.8 episodes, respectively; $P < 0.001$). In addition, immunological assessments showed significant physiological changes, malnourished children had lower counts of absolute lymphocytes and less available micronutrients in serum. Pearson correlation revealed a strong linear inverse association between HFA Z score and total infection period, $r = -0.62$ and $p < 0.001$ as was shown in Table 3. Further comparative assessments showed statistically significant differences in immune indicators and inflammatory markers between the different nutritional strata (as outlined in Table 4).

Table 1: Baseline Demographic and Clinical Characteristics of Participants (N=75)

Variable	Categories / Metric	Total Sample (N=75) / Mean ± SD or n (%)
Age	Months (Mean ± SD)	41.2 ± 8.5
Gender	Male	41 (54.7%)
	Female	34 (45.3%)
Nutritional Status	Well-Nourished	51 (68.0%)
	Moderately Malnourished	24 (32.0%)
Anthropometry	Height-for-Age Z-Score (HAZ)	-1.45 ± 0.62
	Weight-for-Age Z-Score (WAZ)	-1.32 ± 0.58

Table 2: Comparison of Infection Frequency and Duration by Nutritional Status

Clinical Parameter	Well-Nourished (n=51)	Moderately Malnourished (n=24)	p-value
Total Infectious Episodes	1.9 ± 0.8	3.8 ± 1.2	< 0.001

Acute Respiratory Infections	1.2 ± 0.5	2.4 ± 0.9	< 0.001
Diarrheal Episodes	0.7 ± 0.4	1.4 ± 0.6	< 0.001
Total Illness Duration (Days)	8.4 ± 3.1	18.6 ± 5.2	< 0.001

Table 3: Pearson Correlation Matrix Between Nutritional Indices and Clinical Outcomes

Variable Pair	Correlation Coefficient (r)	p-value
Height-for-Age Z-Score vs. Total Infection Frequency	-0.58	< 0.001
Height-for-Age Z-Score vs. Total Illness Duration	-0.62	< 0.001
Absolute Lymphocyte Count vs. Total Infection Frequency	-0.51	< 0.01
Serum Micronutrient Levels vs. Total Illness Duration	-0.45	< 0.01

Table 4: Comparative Analysis of Immunological Parameters Between Subgroups

Immunological Parameter	Well-Nourished Group (Mean ± SD)	Moderately Malnourished Group (Mean ± SD)	p-value
Total Leukocyte Count ($10^3/\mu L$)	8.6 ± 1.8	6.4 ± 1.5	< 0.001
Absolute Lymphocyte Count ($10^3/\mu L$)	4.2 ± 0.9	2.8 ± 0.7	< 0.001
Serum Albumin (g/dL)	4.1 ± 0.4	3.3 ± 0.5	< 0.001
C-Reactive Protein (mg/L)	1.8 ± 0.7	4.2 ± 1.4	< 0.001

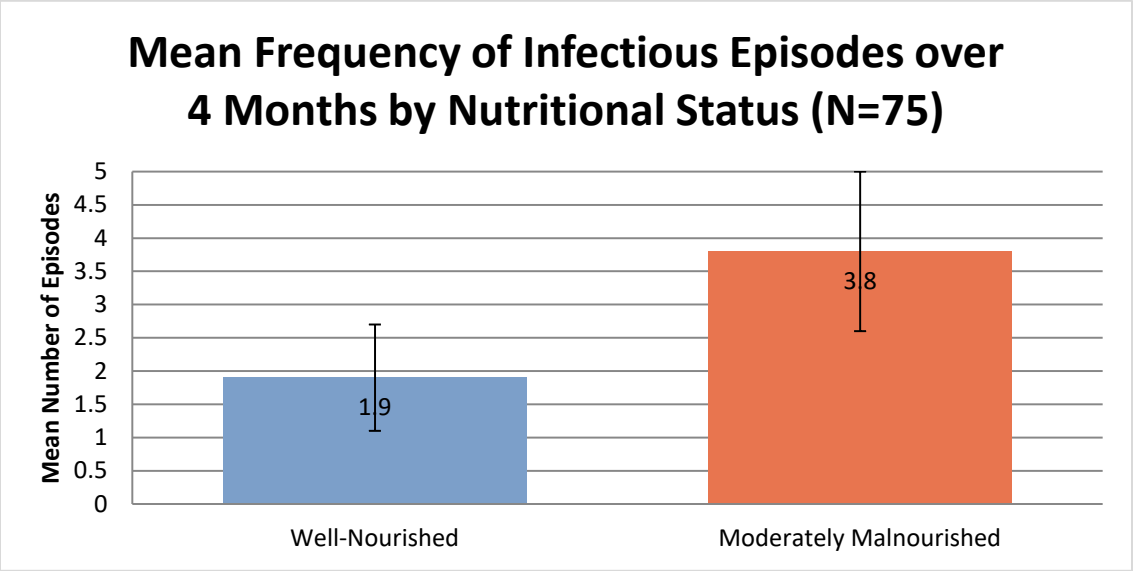


Figure 1 Mean Frequency of Infectious Episodes over 4 Months by Nutritional Status (N=75)

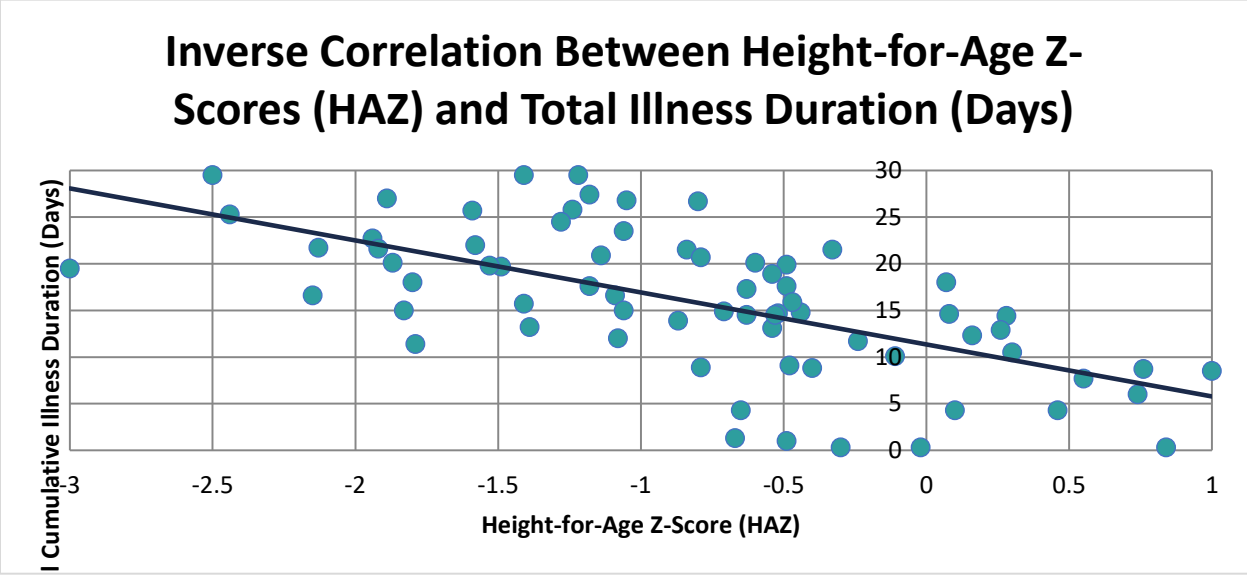


Figure 2 Inverse Correlation Between Height-for-Age Z-Scores (HAZ) and Total Illness Duration (Days)

DISCUSSION

This is a prospective study on a pediatric cohort which explored the intricate association between the nutritional status and immune competence of young children living in Southern Punjab (11). The results showed that the moderately malnourished children had significantly higher no. of ARIs and diarrheal illness and had longer duration as compared to well nourished children. Additionally, immunological assessments showed that there were differences in physiological parameters, particularly in the absolute lymphocyte count and in micronutrient levels in serum, which were reduced in the malnourished group. A strong inverse linear correlation was observed between HtAz and cumulative illness duration, supporting the assumption that subclinical, chronic nutritional deficiencies undermined children's resilience to common, daily infectious challenges (12).

These findings in the wider context of paediatric health, highlighted the very strong biological need for sufficient nutrient availability to the immune system. Moderately malnourished individuals had decreased leukocytes and lymphocytes counts, consistent with the known pathophysiological mechanisms by which chronic macro and micronutrient deficiencies affected cell proliferation, antibody production, and integrity of the mucosal barrier (13). As a result, frontline immune responses became slow and consequently, community pathogens got more persistent infections. However, instead of seeing malnutrition as simply a consequence of frequent illness, the data also strongly suggested a bi-directional relationship in which subclinical growth failure was a direct driver of increased vulnerability to infection, which, in turn, led to continued growth failure and a vicious cycle of malnutrition and disease (14).

The public health implications of the results of this study were significant and led to the introduction of proactive community level nutrition monitoring instead of attention directed at acute hospital interventions (15). Traditional health care systems often focused on severe acute malnutrition and ignored the subtler and more insidious effects of mild to moderate nutritional deficiencies early in life (16). The higher prevalence of infection in children with subclinical deficits suggested the need for built-in routine screening of children by anthropometric parameters and monitoring of immune indicators before clinical emergencies occur (17). The introduction of targeted nutrition supplementation and micronutrient fortification at the community level provided a viable avenue for intervention of immune suppression, and of an enormous burden of preventable pediatric morbidity (18).

It was important to identify the strengths and weaknesses of the methodology used in this study to provide context for the findings. One major advantage was the prospective community based design, which used the biweekly monitoring of caregivers to elicit actual time morbidity data, thus reducing reporting bias (19). The simultaneous recording of accurate anthropometric data and objective immunological parameters provided the study with empirical richness. But there were some drawbacks that should be taken in stride. The limited generalizability of the findings to more diverse urban populations was related to the relatively

small sample size (N = seventy five), and to the geographic setting that was very limited and confined to Southern Punjab. Further, the four-month observation period covered a specific phase of the seasonal climate and other multi-seasonal patterns of infection may be missed, and the study lacked control of other confounding factors, which could affect individual susceptibility (20), such as household hygiene practices and specific dietary diversity.

Based on these findings, future studies were poised to be large-scale multi-center prospective cohorts to confirm these trends over long time periods and many seasons in varying demographic settings (21). Targeted micronutrient interventions to improve specific efficacy of lymphocyte restoration and infection reduction also offered insights into clinical protocol development. The nuanced understanding gained from studies examining the interactions among socioeconomic, environmental and nutritional immune competence in children further developed and fine-tuned preventive strategies that finally led to better immune-competence in vulnerable pediatric populations (22).

CONCLUSION

The present prospective cohort study has proven that even subclinical deficiencies of nutrition during early years adversely affect the immune competence and increase susceptibility to infections. This finding emphasizes the need for preventive approaches and early identification of even subclinical deficiencies of nutrition within communities instead of dealing only with severe cases of malnutrition. Through such an approach, public health campaigns can efficiently boost the immune system of children and decrease preventable infection-related morbidity. This will help in breaking the vicious circle of malnutrition and infection in areas such as Southern Punjab.

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