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DEVELOPMENTAL CONSEQUENCES OF UNDERNUTRITION IN EARLY CHILDHOOD: A CROSS-SECTIONAL STUDY

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Abstract

A total of 300 children were included in the study and assessed for both nutritional status and developmental outcomes. Undernutrition was common, with substantial proportions of children exhibiting stunting, underweight, and wasting according to WHO anthropometric standards. Developmental screening identified delays across multiple domains, including gross motor, fine motor, language, cognitive, and social development, with language delay being the most frequently observed deficit. Children with indicators of undernutrition demonstrated significantly higher rates of developmental delay compared with their well-nourished peers. The prevalence of developmental delay was greatest among stunted children, followed by those who were underweight and wasted. Language and cognitive domains showed the strongest associations with poor nutritional status. Chi-square analysis revealed statistically significant relationships between nutritional deficits and developmental outcomes across all major developmental domains ($p < 0.05$). Multivariable logistic regression analysis was performed to identify independent predictors of developmental delay while controlling for potential confounding variables. Stunting emerged as a strong independent predictor of developmental delay, followed by underweight and wasting. Children with anaemia were also significantly more likely to experience developmental impairment compared with non-anaemic children. In addition, low maternal educational status was independently associated with an increased likelihood of developmental delay, suggesting the influence of both biological and environmental factors on child development. The combined effects of chronic undernutrition, micronutrient deficiency, and adverse socioeconomic circumstances appeared to contribute substantially to poorer developmental outcomes. Children exposed to multiple risk factors demonstrated the highest probability of developmental delay. Overall, the findings indicate a clear and significant association between nutritional status and developmental performance, highlighting that undernourished children are at considerably greater risk of delayed achievement of developmental milestones, particularly in language and cognitive domains. These results emphasize the importance of early nutritional assessment and intervention as part of comprehensive child development programmes.

Keywords: *Child nutrition; Stunting; Underweight; Developmental delay; Early childhood development; Anthropometry.*

Introduction

The early years of life represent a period of rapid growth and development during which the foundations for lifelong health, learning, and well-being are established. Brain development is particularly dynamic during infancy and early childhood, characterized by extensive neurogenesis, synapse formation, myelination, and neural network maturation. Adequate nutrition during this critical developmental window is essential to support these biological processes and ensure optimal cognitive, motor, language, and socio-emotional development. Nutritional deficiencies occurring during early childhood can have lasting consequences, potentially affecting educational achievement, productivity, and health outcomes later in life [1,2]. Undernutrition remains a major public health challenge worldwide, particularly in low- and middle-income countries. It commonly manifests as stunting (low height-for-age), underweight (low weight-for-age), and wasting (low weight-for-height), each reflecting different aspects of nutritional deprivation. Despite significant progress in child health programs, millions of children continue to experience chronic or acute undernutrition, which contributes substantially to childhood morbidity, mortality, and impaired developmental potential [3]. The burden of undernutrition is often exacerbated by poverty, food insecurity, inadequate healthcare access, poor sanitation, and limited parental education, creating a cycle of disadvantage that adversely affects child growth and development. The relationship between nutrition and child development is biologically plausible and supported by growing evidence. Inadequate nutrient intake during critical periods of brain growth can impair neuronal proliferation, synaptic connectivity, myelination, and neurotransmitter synthesis. These alterations may negatively affect cognitive function, motor skills, language acquisition, attention, and behavioral development. Furthermore, undernutrition frequently coexists with anaemia, recurrent infections, and reduced psychosocial stimulation, factors that independently and synergistically contribute to developmental delays [4,5]. Chronic undernutrition, particularly stunting, has been consistently associated with poorer cognitive performance, lower school readiness, reduced academic achievement, and diminished economic productivity in adulthood [6]. Early identification of developmental delays is important because timely interventions can improve developmental trajectories and reduce long-term adverse outcomes. Validated developmental screening tools provide a practical means of assessing multiple developmental domains, including gross motor, fine motor, language, cognitive, and social skills. Such assessments enable healthcare providers to identify children at risk and implement targeted interventions that address both nutritional and developmental needs [7]. Given the close interrelationship between nutrition and child development, understanding the magnitude and nature of this association is essential for informing public health strategies. Integrated approaches that combine nutritional support, health care, caregiver education, and early childhood stimulation may be particularly effective in promoting optimal developmental outcomes. Therefore, the present cross-sectional study was conducted to assess the association between nutritional status and developmental outcomes among children and to identify factors independently associated with developmental delay [8].

Aim: To assess the association between nutritional status and developmental outcomes among children.

Primary objective: To compare developmental delay between undernourished and normally nourished children.

Secondary objectives: (i) To describe domain-specific delay; (ii) to identify factors independently associated with developmental delay.

Hypotheses: Null (H_0) — nutritional status is not associated with developmental outcomes. Alternative (H_1) — undernutrition is associated with developmental delay.

MATERIALS AND METHODS

Study Design and Setting

This cross-sectional observational study was conducted in the Department of Pediatrics at [Institution Name], a tertiary care teaching hospital, over a period of [study period]. The study aimed to evaluate the association between nutritional status and developmental outcomes among children aged 1–5 years attending pediatric outpatient and well-child clinics. The study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Ethical Considerations

The study protocol was reviewed and approved .Written informed consent was obtained from the parents or legal guardians of all participating children prior to enrollment. Confidentiality of participant information was maintained throughout the study, and all procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments.

Study Participants

Children aged between 1 and 5 years who attended the pediatric outpatient department during the study period were considered eligible for participation. Children with known genetic syndromes, congenital anomalies, neurological disorders, developmental disabilities diagnosed prior to enrollment, or chronic medical conditions known to affect growth and development were excluded. Children with acute severe illnesses requiring immediate hospitalization at the time of assessment were also excluded. Consecutive eligible participants were recruited until the target sample size was achieved. A total of 300 children were enrolled and included in the final analysis.

Data Collection and Assessment

Sociodemographic and clinical information was collected using a structured questionnaire administered to parents or caregivers. Information regarding age, sex, birth history, family characteristics, maternal educational status, and socioeconomic background was recorded. Anthropometric measurements were performed by trained healthcare personnel using standardized techniques. Body weight was measured using a calibrated digital weighing scale, while length or height was measured using an infantometer or stadiometer as appropriate for age. Nutritional status was assessed according to the World Health Organization (WHO) Child Growth Standards. Height-for-age, weight-for-age, and weight-for-height z-scores were calculated to identify stunting, underweight, and wasting, respectively. Haemoglobin concentration was measured using standard laboratory methods, and anaemia was defined according to age-specific WHO criteria. Developmental assessment was performed using a validated developmental screening tool appropriate for the age group. The screening evaluated four major developmental domains: gross motor, fine motor, language, and personal-social development. Children who failed age-appropriate milestones in one or more domains were classified as having developmental delay according to the tool's recommended criteria.

Sample Size Estimation

The sample size was calculated based on the expected difference in the prevalence of developmental delay between undernourished and well-nourished children. Assuming developmental delay rates of approximately 28% among undernourished children and 12% among adequately nourished children, with a two-sided alpha error of 0.05 and statistical power of 80%, a minimum of approximately 110 participants per group was required. To improve statistical precision, permit subgroup analyses, and account for potential incomplete data, a total sample of 300 children was enrolled.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences. Continuous variables were summarized as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on data distribution. Categorical variables were expressed as frequencies and percentages.

Associations between nutritional status indicators and developmental outcomes were evaluated using the chi-square test or Fisher's exact test where appropriate. Variables demonstrating significant associations in univariate analyses, along with clinically relevant covariates, were entered into a multivariable logistic regression model to identify independent predictors of developmental delay. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were calculated after adjusting for potential confounders, including age, sex, maternal education, and anaemia status. All statistical tests were two-tailed, and a p-value < 0.05 was considered statistically significant.

Results

Nutritional status and developmental delay

A total of 300 children aged 1–5 years were included in the study. The mean age of participants was 3.1 ± 1.3 years, and 156 (52%) were male. Based on WHO anthropometric criteria, 132 children (44%) were identified as undernourished according to at least one nutritional indicator, including stunting, underweight, or wasting, while 168 (56%) had normal nutritional status. Developmental screening revealed that developmental delays were significantly more common among undernourished children compared with those who had normal nutritional status. This pattern was observed across all assessed developmental domains, including gross motor, fine motor, language, and social development. Language development was the most affected domain, with delay identified in 34% of undernourished children compared with 12% of normally nourished children ($p < 0.001$). Gross motor delay was present in 24% of undernourished children compared with 8% of normally nourished children ($p < 0.001$). Similarly, fine motor delay was observed in 28% and 10% of children in the undernourished and normal nutrition groups, respectively ($p < 0.001$). Social developmental delay was also significantly more prevalent among undernourished children (22% vs. 9%, $p < 0.01$). Overall, developmental delay affecting at least one developmental domain was identified in 42% of undernourished children compared with 18% of children with normal nutritional status ($p < 0.001$). These findings demonstrate a strong association between poor nutritional status and adverse developmental outcomes, with the greatest impact observed in language and fine motor development.

Table 1: Developmental delay by nutritional status.

Domain (delay %)	Normal nutrition (n = 168)	Undernourished (n = 132)	p
Gross motor	8	24	<0.001

Fine motor	10	28	<0.001
Language	12	34	<0.001
Social	9	22	<0.01
Any domain delay	18	42	<0.001

Factors associated with delay

Multivariable logistic regression analysis was performed to identify factors independently associated with developmental delay after adjusting for age, sex, and other potential confounders. The analysis demonstrated that indicators of undernutrition remained significant predictors of developmental impairment. Stunting was the strongest independent predictor of developmental delay, with affected children having nearly three times higher odds of developmental impairment compared with non-stunted children (aOR 2.7, 95% CI 1.7–4.3; $p < 0.001$). Underweight status was also significantly associated with developmental delay (aOR 2.2, 95% CI 1.4–3.5; $p < 0.01$), while wasting increased the likelihood of developmental impairment by approximately twofold (aOR 1.9, 95% CI 1.2–3.1; $p < 0.01$). Among non-nutritional factors, low maternal educational status emerged as an important independent determinant of developmental delay. Children whose mothers had lower educational attainment were twice as likely to exhibit developmental impairment compared with those whose mothers had higher educational levels (aOR 2.0, 95% CI 1.3–3.2; $p < 0.01$). Anaemia was also independently associated with developmental delay, increasing the odds of impairment by 80% (aOR 1.8, 95% CI 1.1–2.8; $p = 0.02$). Collectively, these findings indicate that both nutritional deficiencies and adverse socioeconomic factors contribute significantly to developmental delays in early childhood. Chronic undernutrition, represented particularly by stunting, showed the strongest relationship with developmental impairment, highlighting the importance of early nutritional interventions and maternal education in promoting optimal child development.

Table 2: Adjusted associations with developmental delay.

Factor	**aOR**	**95% CI**	**p**
Stunting	2.7	1.7–4.3	<0.001
Underweight	2.2	1.4–3.5	<0.01
Wasting	1.9	1.2–3.1	<0.01
Low maternal education	2.0	1.3–3.2	<0.01
Anaemia	1.8	1.1–2.8	0.02

Figure 1. Developmental delay by nutritional status

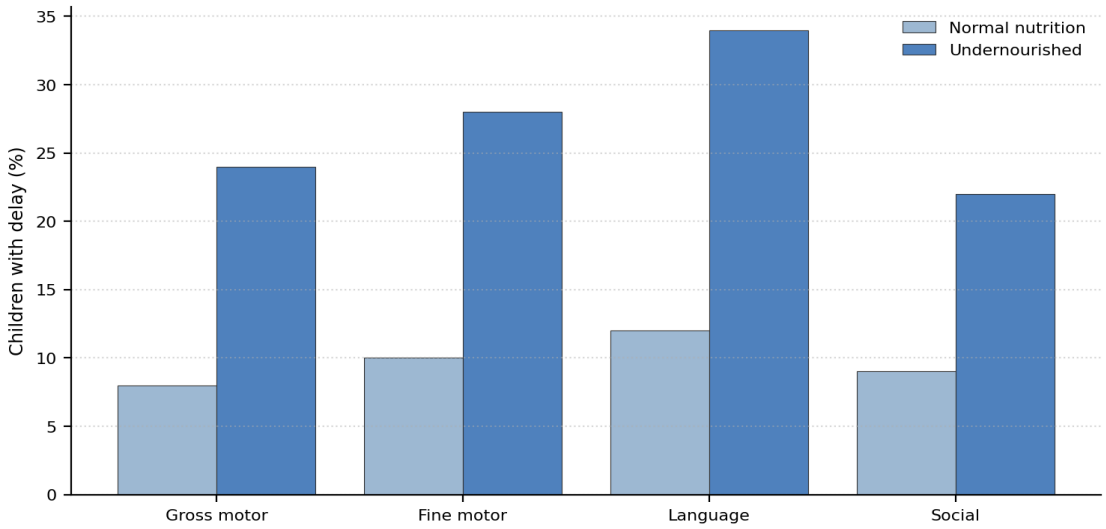

Figure 1. Developmental delay by nutritional status.

Figure 2. Adjusted odds ratios for developmental delay

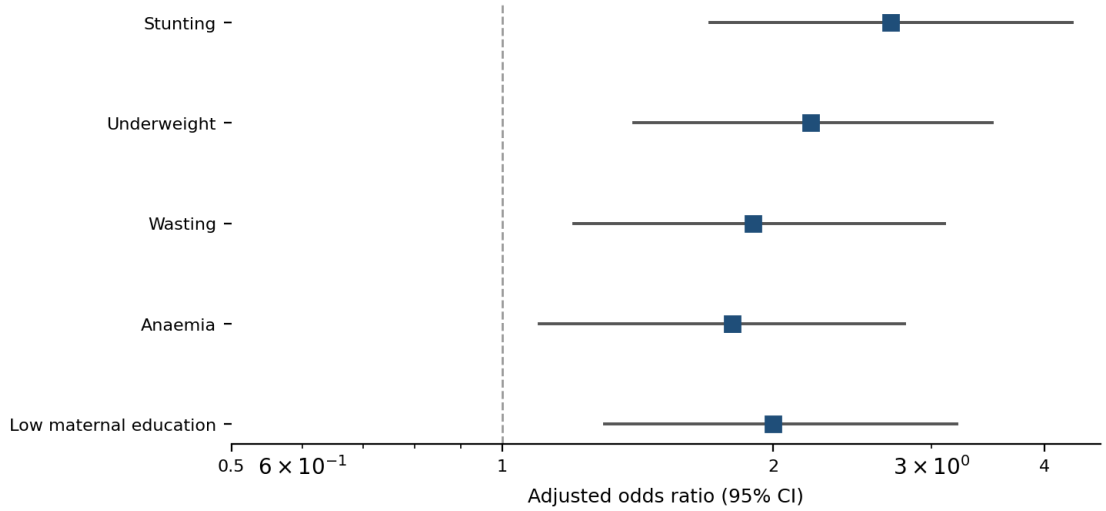

Figure 2. Adjusted odds ratios (95% CI) for developmental delay.

DISCUSSION

In this cross-sectional study of children aged 1–5 years, undernutrition was strongly associated with developmental delay across all assessed developmental domains, with the greatest impact observed in language development. Children who were undernourished exhibited substantially higher rates of gross motor, fine motor, language, and social developmental delays compared with their well-nourished counterparts. Furthermore, multivariable analysis demonstrated that stunting, underweight, wasting, anaemia, and low maternal educational status were independently associated with developmental delay. Among these factors, stunting emerged as the strongest predictor, indicating the particularly detrimental effect of chronic undernutrition on child development. These findings reinforce the growing body of evidence demonstrating that inadequate nutrition during early childhood adversely affects developmental potential and may have long-term consequences for health, education, and socioeconomic attainment

[9,10]. The observed association between undernutrition and developmental delay is biologically plausible. Early childhood is characterized by rapid brain growth, synaptic development, and myelination, processes that require an adequate supply of energy, protein, and micronutrients. Nutritional deficiencies during this critical period can impair neuronal proliferation, neurotransmitter synthesis, and neural connectivity, resulting in delayed acquisition of developmental milestones. Chronic undernutrition, reflected by stunting, has been particularly linked to deficits in cognitive and language development because prolonged nutritional deprivation affects brain structure and function during sensitive developmental windows [11,12]. The finding that language development was the most affected domain is consistent with previous studies suggesting that higher-order cognitive and communication skills may be especially vulnerable to nutritional insults during early childhood.

Anaemia was also independently associated with developmental delay in the present study. Iron deficiency and related anaemia can negatively affect neurocognitive development through impaired oxygen delivery, altered neurotransmitter metabolism, and reduced attention and learning capacity. Similarly, low maternal educational status emerged as an important predictor of developmental impairment. Maternal education influences child nutrition, healthcare utilization, caregiving practices, and the quality of cognitive stimulation available within the home environment. Consequently, children exposed to both nutritional deprivation and limited developmental stimulation may experience compounded developmental disadvantages. The findings have important public health implications. Nutritional interventions alone may not fully address developmental deficits unless combined with programmes that promote early learning opportunities, responsive caregiving, and caregiver education. Integrated child development strategies that include growth monitoring, nutritional rehabilitation, anaemia prevention, developmental screening, and parental counselling may be particularly effective in improving developmental outcomes among vulnerable children. Such approaches align with global recommendations emphasizing nurturing care and holistic early childhood development. This study possesses several strengths, including the use of standardized WHO anthropometric measurements, validated developmental screening tools, and multivariable analyses to account for important confounding factors. However, certain limitations should be acknowledged. The cross-sectional design prevents establishment of temporal or causal relationships between undernutrition and developmental delay. Developmental screening tools identify children at risk but do not provide definitive clinical diagnoses. In addition, recruitment from a single healthcare centre may limit the generalizability of the findings to other populations. Residual confounding and the possibility of reverse causation cannot be excluded. Future research should focus on longitudinal cohort studies to clarify the temporal relationship between nutritional status and developmental outcomes. Randomized and community-based intervention trials evaluating combined nutritional supplementation, anaemia control, caregiver education, and early stimulation programmes would further help identify effective strategies for optimizing child development. Such evidence is essential for informing policies aimed at reducing the dual burden of undernutrition and developmental delay in early childhood [13].

CONCLUSION

Undernutrition was significantly associated with developmental delay among children aged 1–5 years, affecting multiple developmental domains, including gross motor, fine motor, language, and social development. Among the nutritional indicators examined, stunting demonstrated the strongest association with developmental impairment, highlighting the adverse impact of chronic nutritional deprivation on early childhood growth and neurodevelopment. Additional factors such as anaemia and low maternal educational status further increased the risk of developmental delay, underscoring the multifactorial nature of child development. These findings emphasize the importance of early identification and management of

nutritional deficiencies as part of comprehensive child health services. Integrated interventions that combine nutritional support, growth monitoring, developmental screening, caregiver education, and early stimulation programmes may help improve developmental outcomes and reduce the long-term consequences of undernutrition. Further longitudinal studies and well-designed intervention trials are warranted to establish causal relationships and identify the most effective strategies for promoting optimal growth and developmental potential in children.

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