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Original Article

Effect of Nutritional Rehabilitation on Neurodevelopmental Status of Children with Severe Acute Malnutrition (SAM)

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ABSTRACT

Severe acute malnutrition (SAM) is a major public health problem in children, contributing to high morbidity, mortality, and impaired neurodevelopment. While nutritional rehabilitation improves survival and physical growth, its effect on cognitive, motor, language, and social development remains inadequately explored. **Objective:** To evaluate the impact of nutritional rehabilitation on neurodevelopmental outcomes in children aged 1–6 years with SAM. **Methods:** This prospective observational study was conducted over six months in the Department of Paediatrics of Khairpur Medical College, Sindh. A total of 150 children aged 1–6 years diagnosed with SAM (according to WHO criteria: weight-for-height Z-score < −3 SD or mid-upper arm circumference < 11.5 cm) were enrolled. Participants received eight weeks of standardized nutritional rehabilitation, including therapeutic feeding and micronutrient supplementation, along with management of associated complications. Anthropometric parameters and neurodevelopmental domains (cognitive, motor, language, and social) were assessed at baseline and post-intervention. Data were analysed using SPSS version 23, applying paired t-tests and chi-square tests, with $p<0.05$ considered significant. **Results:** Significant improvements were observed in weight (7.3 ± 1.4 vs. 9.2 ± 1.6 kg), MUAC (10.4 ± 0.9 vs. 12.5 ± 1.1 cm), and weight-for-height Z-score (−3.42 ± 0.51 vs. −2.18 ± 0.47) ($p < 0.001$). Neurodevelopmental scores improved significantly across all domains ($p < 0.001$). The proportion of children with normal development increased from 20.0% to 53.3%, while moderate developmental delay decreased from 33.3% to 14.7%. **Conclusions:** Nutritional rehabilitation significantly improves both growth and neurodevelopment in children with SAM. Early identification and timely intervention are crucial for optimal developmental recovery.

INTRODUCTION

It is estimated that approximately 13.6 million children under five years of age globally experience severe acute malnutrition (SAM) annually [1], which contributes substantially to childhood morbidity and mortality, with SAM accounting for an estimated 1.1 million child deaths each year [2]. The typical clinical features of SAM include severe wasting (weight-for-height Z-score < -3 standard deviations), nutritional edema (bilateral pitting edema), and mid-upper arm circumference (MUAC) < 11.5 cm as per the World Health Organization (WHO) growth standards [3]. Beyond its immediate life-threatening consequences, severe malnutrition exerts profound effects on physical growth and development [4], causes significant immunological dysfunction predisposing to recurrent infections [5], and critically impairs neurodevelopmental outcomes including cognitive, motor, language, and social-emotional domains that may persist long after nutritional recovery [6,7]. Nutritional rehabilitation is a treatment that has been made to control the SAM via therapeutic feeding, micronutrient supplements, and medical control of

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complications [8]. These treatments have been demonstrated to positively impact the survival and nutritional condition. Nonetheless, there is an increasing interest in the literature on the recovery of neurodevelopmental functioning after nutritional rehabilitation. The determination of weight gain and anthropometric recovery is usually the measure of a successful treatment, but it might not be the complete measure of a functional recovery in children who experience SAM. Neurodevelopmental evaluation is consequently necessary to assess the overall effect of the nutritional rehabilitation on the cognitive and motor outcomes. The adverse effects of severe malnutrition on brain development and cognitive abilities have been noted in a number of studies [9]. Children exposed to early malnutrition have been shown to perform significantly worse in cognitive function and academic achievement compared to well-nourished peers, likely due to impaired neuronal development and synaptic connectivity [10]. Similarly, early-life nutritional deficiencies have been associated with delayed cognitive and motor development [11]. Evidence also suggests that malnourished children exhibit delayed developmental milestones and lower intelligence quotient (IQ) scores, although timely nutritional rehabilitation may partially improve these outcomes [12]. Furthermore, improvements in motor and cognitive development have been observed following therapeutic feeding programs; however, some developmental deficits may persist despite nutritional recovery, emphasizing the importance of early intervention [13]. Studies have also indicated that combining nutritional rehabilitation with psychosocial stimulation results in better neurodevelopmental outcomes compared to nutritional therapy alone [14].

Nevertheless, such findings are only supported by a limited number of studies that assessed neurodevelopmental changes pre- and post-nutritional rehabilitation with standardized developmental assessment measures. Hence, additional studies are needed to determine the degree to which nutritional rehabilitation plays a role in the recovery of neurodevelopment in children with severe acute malnutrition. Therefore, this study aims to evaluate the impact of nutritional rehabilitation on neurodevelopmental outcomes in children with severe acute malnutrition, with a focus on assessing changes in cognitive and motor development before and after treatment.

METHODS

This prospective observational study was conducted in the Department of Pediatrics of a tertiary care hospital over a period of six months from October 2025 to April 2026. Ethical approval was obtained from the Institutional Review Board of Khairpur Medical College, Khairpur Mir's Sindh (Ref. No. KMC/RERC/113; dated 1st October, 2025). A total of 150 children aged 1–6 years diagnosed with severe acute malnutrition (SAM) were enrolled through consecutive sampling. SAM was defined according to the World Health Organization criteria, including a weight-for-height Z-score < –3 standard deviations or mid-upper arm circumference (MUAC) < 11.5 cm [15]. Children with congenital neurological disorders, genetic syndromes, chronic systemic illnesses, or recent treatment for SAM were excluded. Informed consent was obtained from parents or guardians before enrollment. All participants received standard nutritional rehabilitation based on WHO guidelines, including therapeutic feeding (F-75 and F-100), Ready-to-Use Therapeutic Food (RUTF), micronutrient supplementation, and management of associated infections [16]. The rehabilitation period lasted for eight weeks. Neurodevelopmental status was assessed using a standardized developmental screening tool covering cognitive, motor, language, and social domains. Neurodevelopmental status was assessed using the ShaMaq Developmental Screening Tool (SDST), a validated tool for Pakistani children demonstrating strong psychometric properties including internal consistency (α = 0.78–0.94), inter-observer reliability (0.74–1.0), sensitivity (94.4%), and specificity (92.9%) [17]. Assessments were performed at baseline and after completion of the rehabilitation program. Anthropometric measurements (weight, height/length, and MUAC) were recorded at baseline and post-intervention using standard procedures. Weight-for-height Z-scores were calculated to evaluate nutritional status.

Data were analyzed using SPSS version 23. Descriptive statistics were used to summarize variables. Paired t-test was applied to compare pre- and post-rehabilitation outcomes, while the chi-square test was used for categorical variables. A p-value <0.05 was considered statistically significant.

RESULTS

The study used 150 children aged 1-6 years with a diagnosis of severe acute malnutrition to determine the impact of nutritional rehabilitation on anthropometric and neurodevelopmental outcomes. The baseline demographic traits, anthropometric variables, and neurodevelopmental scores were measured before the nutritional rehabilitation began and re-measured after eight weeks of rehabilitation program implementation. Most of the respondents were between 1 and 3 years of age (57.3%), which means that young children are susceptible to severe acute malnutrition at earlier developmental stages. It was found that a slightly greater percentage of male children (54%) was found than female (46%) (Table 1).

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Table 1: Demographic Characteristics of the Study Participants (n = 150)

Variables	n (%)
Age Group	
1–3 years	86 (57.3%)
4–6 years	64 (42.7%)
Gender	
Male	81 (54%)
Female	69 (46%)

Significant improvements were observed in all anthropometric parameters following nutritional rehabilitation (Table 2). Mean weight increased from 7.3 ± 1.4 kg to 9.2 ± 1.6 kg ($p<0.001$). Height increased from 78.1 ± 6.5 cm to 79.6 ± 6.8 cm ($p = 0.021$), indicating a statistically significant improvement. MUAC increased from 10.4 ± 0.9 cm to 12.5 ± 1.1 cm ($p < 0.001$). Weight-for-Height Z-score improved from −3.42 ± 0.51 to −2.18 ± 0.47 ($p<0.001$), indicating recovery from severe to moderate malnutrition (Table 2).

Table 2: Comparison of Anthropometric Parameters Before and After Nutritional Rehabilitation

Parameters	Baseline (Mean ± SD)	Post-Rehabilitation (Mean ± SD)	p-value
Weight (kg)	7.3 ± 1.4	9.2 ± 1.6	<0.001
Height (cm)	78.1 ± 6.5	79.6 ± 6.8	0.021
MUAC (cm)	10.4 ± 0.9	12.5 ± 1.1	<0.001
Weight-for-height Z score	−3.42 ± 0.51	−2.18 ± 0.47	<0.001

Statistical test applied: Paired t-test

These data show considerable improvements in all developmental areas after nutritional rehabilitation. The scores on cognitive development at baseline were 64.2 and at the end of the rehabilitation were 73.5, with a $p<0.001$ indicating improved cognitive function in the form of attention, memory, and problem solving. The scores of motor development increased to 72.4 ± 7.6 ($p<0.001$) as compared to 62.7 ± 8.5, which is a reflection of better gross and fine motor skills, coordination, and physical activity. The development of language was also of the same pattern, which improved from 61.8 ± 8.1 to 71.6 ± 7.5 ($p<0.001$), indicating an improvement in communication, understanding, and expression skills. The scores in social development rose between 65.1 ± 7.6 and 74.3 ± 6.9 ($p=0.001$), which showed the improvement of social interaction and emotional control, as well as adaptive behaviors (Table 3).

Table 3: Neurodevelopmental Scores Before and After Nutritional Rehabilitation

Developmental Domain	Baseline Score (Mean ± SD)	Post-Rehabilitation Score (Mean ± SD)	p-value
Cognitive Development	64.2 ± 7.9	73.5 ± 7.1	<0.001
Motor Development	62.7 ± 8.5	72.4 ± 7.6	<0.001
Language Development	61.8 ± 8.1	71.6 ± 7.5	<0.001
Social Development	65.1 ± 7.6	74.3 ± 6.9	<0.001

Statistical test applied: Paired t-test

On the baseline, only 30 (20.0%) were found to be normally developed, with most showing mild 70 (46.7%) and moderate developmental delay 50 (33.3%). The percentage of children with developmental normalization was also significantly higher after the intervention, 80 (53.3%), demonstrating a significant improvement in the overall development processes. In line with this, children with mild developmental delay were reduced to 48 (32%), and those with moderate developmental delay were reduced to 22 (14.7%) (Figure 1).

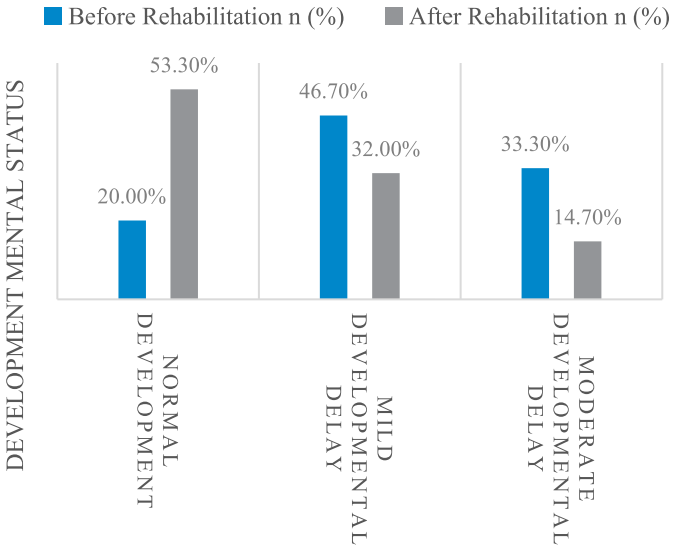


Figure 1: Demonstrates a shift from moderate/mild delay toward normal developmental status following intervention

The results of the current paper confirm the statement that nutritional rehabilitation positively affected anthropometric and neurodevelopmental outcomes in children with severe acute malnutrition aged 1 to 6. The increase in weight gain, MUAC, and weight-for-height Z-scores, and the drastic development gains in the cognitive, motor, language, and social domains of development were observed.

DISCUSSION

The current study observed changes in neurodevelopmental status following nutritional rehabilitation among children with severe acute malnutrition. The results showed a substantial improvement in the anthropometric parameters and neurodevelopmental results after eight weeks of the nutritional rehabilitation process [15]. These findings underscore the great significance of timely nutritional intervention in enhancing the physical growth in addition to developmental outcomes among the malnourished children. In the present study, most of the participants

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were aged 1-3 years, which is more than one-half of the study population. This is the age group that is equivalent to a very critical period of rapid brain growth and development, where children are mostly susceptible to the negative impacts of malnutrition [16]. Neurodevelopmental improvements were assessed using the ShaMaq Developmental Screening Tool (SDST), a culturally validated instrument for Pakistani children with high sensitivity (94.4%) and specificity (92.9%) [17]. Similar results were also documented by a previous study, which noted that early childhood malnutrition has a major impact on the development of the brain, its cognitive processes, and developmental prospects. Childhood is thus regarded as a sensitive period whereby a lack of nutrients during early childhood may create extended developmental effects [18]. The current research has shown that there is a statistically significant increase in anthropometric indicators after nutrition rehabilitation. The mean body weight and MUAC were found to be significantly better than before the intervention period, whereas the weight-height-Z-score was also found to have improved significantly [19]. The results align with the past studies by found that therapeutic feeding programs for severe acute malnutrition result in rapid nutritional status improvement and a reduction of the morbidity and mortality rates among children with such conditions. Micronutrient intake and therapeutic diets through nutritional rehabilitation are sources of the essential nutrients required to support growth, tissue repair, and recovery of immunity [19]. In addition to anthropometric recovery, there were also significant neurodevelopmental outcomes in every domain measured in the current study, such as cognitive, motor, language, and social development. Such improvements suggest that the issue of proper nutritional rehabilitation can be effectively used to positively impact the neurological recovery and functional development of children with severe acute malnutrition. These observations were also provided by a previous study, had shown that appropriate nutrition in early childhood is beneficial in terms of neuronal development, synaptic connectivity, and cognitive functioning. This study also supports the results of previous literature, which noted that nutritional interventions and the use of micronutrient supplements can lead to significant developmental improvements among undernourished children [20]. Better motor functioning can be explained by greater muscle mass and better physical strength through nutritional recovery, whereas greater language and cognitive performance can be explained by better brain functioning and being more sensitive to external stimuli [21]. Moreover, the incidence of children who were reported to be in normal developmental status improved significantly after the nutritional rehabilitation therapy, whereas the percentage of children with moderate developmental delay reduced significantly. These results imply that nutritional rehabilitation not only enhances physical growth, but also functional developmental recovery [22]. This tendency was also observed in one longitudinal study, which found that the children with severe malnutrition who were given nutritional support showed a notable enhancement in developmental performance after that nutritional intervention. Although the improvements were observed, even after rehabilitation, a percentage of the children in the current study still exhibited mild or moderate delays in development. This observation is in line with previous studies that show that the impact of early childhood malnutrition on brain development may not be entirely reversible, especially where nutritional deprivation is experienced at critical stages of neurological development [23]. Thus, although dietary rehabilitation is of primary importance in the treatment of severe acute malnutrition, complex interventions such as early stimulation programs, education of caregivers, and psychosocial support can also have an additional positive impact on neurodevelopmental outcomes. It is possible that developmental stimulation can be incorporated in nutritional rehabilitation programs to achieve maximum developmental potential in children who have suffered severe acute malnutrition. On the whole, the results of the given research confirm the available evidence that nutritional rehabilitation has a great positive impact on physical and neurodevelopmental outcomes of children with severe acute malnutrition. Early diagnoses and timely treatment are essential to ensure the reduction of long-term developmental lapses and the healthy growth of a child.

Several limitations should be considered when interpreting these findings. First, the absence of a control group means the observed improvements cannot be attributed exclusively to nutritional rehabilitation; changes may reflect natural growth, regression to the mean, or concurrent medical care. Accordingly, findings should be interpreted as associations rather than causation. Second, the eight-week follow-up is insufficient to determine whether developmental improvements are sustained long-term. Third, the lack of blinded outcome assessors may have introduced detection bias. Fourth, important confounders—including socioeconomic status, maternal education, and home environment—were not accounted for. Fifth, no standardized protocol was used for managing associated infections and comorbidities, which may have independently influenced outcomes. Finally, consecutive sampling without a defined sampling frame limits the generalizability of findings to the broader SAM population.

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CONCLUSIONS

Children with severe acute malnutrition demonstrated significant improvements in anthropometric and neurodevelopmental outcomes following an eight-week nutritional rehabilitation program. Early identification and timely intervention are essential to enhance recovery and minimize long-term developmental deficits. Integrating nutritional therapy with comprehensive child health programs is crucial for optimal growth and development.

Authors' Contribution

Conceptualization: TAS
Methodology: B, UB
Formal analysis: B, NB
Writing and Drafting: UB, RQ, NB, WA
Review and Editing: TAS, B, UB, RQ, NB, WA

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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