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Original Research Article

AN OBSERVATIONAL STUDY ON ASSESSMENT OF NEURODEVELOPMENTAL STATUS OF SEVERE ACUTE MALNOURISHED CHILDREN USING BAYLEY SCALE OF INFANT AND TODDLER DEVELOPMENT IV (BSID-IV) AT TERTIARY CARE CENTER

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ABSTRACT

Background: Severe acute malnutrition (SAM) adversely affects brain development and is an important cause of cognitive and motor developmental delay in young children. Early identification of neurodevelopmental impairment is essential to optimize rehabilitation and improve long-term outcomes. The objective is to assess the neurodevelopmental status of children aged 6–42 months with severe acute malnutrition using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV) and to evaluate changes following nutritional rehabilitation.

Materials and Methods: This prospective observational study was conducted at the Indira Gandhi Institute of Child Health, Bengaluru, from July 2023 to December 2024. Fifty children with severe acute malnutrition fulfilling WHO criteria were enrolled. Following stabilization, neurodevelopment was assessed using BSID-IV. Developmental Quotient (DQ) and Growth Scale Values (GSV) were recorded at baseline and reassessed three months after discharge. Data were analyzed using paired sample t-test.

Results: Most children (92%) were younger than 24 months. Developmental delay was observed in cognition (32%), fine motor (42%), and gross motor (70%) domains, while no delay was identified in receptive or expressive communication. Significant improvement was observed after nutritional rehabilitation in cognition DQ (73.97±6.96 to 87.95±3.88), fine motor DQ (72.13±8.36 to 87.95±3.34), and gross motor DQ (68.97±6.59 to 87.58±4.07) ($p<0.001$ for all). Growth Scale Values also improved significantly across all developmental domains.

Conclusion: Severe acute malnutrition is associated with significant neurodevelopmental delay, predominantly affecting motor and cognitive functions. Early nutritional rehabilitation together with developmental stimulation significantly improves developmental outcomes. Routine developmental screening using BSID-IV should be incorporated into the comprehensive management of children with severe acute malnutrition.

Keywords: Severe acute malnutrition, Bayley Scale of Infant and Toddler Development-IV, Neurodevelopment, Developmental Quotient, Growth Scale Value, Cognitive development, Motor development.

INTRODUCTION

Severe acute malnutrition (SAM) remains one of the leading causes of morbidity and mortality among children under five years of age, particularly in low- and middle-income countries. According to the World Health Organization (WHO), SAM is defined as weight-for-height below −3 standard deviations of the WHO Child Growth Standards, a mid-upper arm circumference (MUAC) less than 11.5 cm, or the presence of bilateral nutritional edema. Despite improvements in child health programs, SAM continues to be a major public health problem, contributing substantially to childhood deaths and long-term disability.[1]

Malnutrition affects nearly every organ system, with the developing brain being particularly vulnerable during infancy and early childhood. Inadequate intake of essential nutrients during this critical period interferes with neuronal proliferation, myelination, synaptogenesis, and neurotransmitter synthesis, resulting in impaired cognitive, language, motor, and socio-emotional development. Children with SAM are therefore at increased risk of developmental delay, poor school performance, reduced productivity, and adverse health outcomes later in life.[2,3]

Early childhood represents a crucial period for brain growth and neurodevelopment, during which environmental stimulation and adequate nutrition play complementary roles. Previous studies have demonstrated that children with severe malnutrition frequently exhibit deficits in cognitive function, motor skills, language acquisition, and adaptive behavior. If left untreated, these impairments may persist despite nutritional recovery, emphasizing the need for early developmental assessment and intervention.[4,5]

The Bayley Scales of Infant and Toddler Development, Fourth Edition (BSID-IV), is a standardized and validated tool designed to assess developmental functioning in children from infancy to 42 months of age. It evaluates multiple developmental domains, including cognition, language, motor, social-emotional, and adaptive behavior, allowing early identification of developmental delay and monitoring of developmental progress following therapeutic interventions.[6,7]

Although nutritional rehabilitation forms the cornerstone of SAM management, limited data are available regarding neurodevelopmental outcomes among Indian children with severe acute malnutrition, particularly using standardized developmental assessment tools such as BSID-IV. Assessing neurodevelopment before and after nutritional rehabilitation can provide valuable information regarding the effectiveness of treatment and the need for early developmental interventions.[8]

Therefore, the present study was undertaken to assess the neurodevelopmental status of children aged 6–42 months with severe acute malnutrition using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV), and to evaluate changes in developmental outcomes following nutritional rehabilitation at a tertiary care center.

MATERIALS AND METHODS

Study Design: This was a prospective observational study conducted to assess the neurodevelopmental status of children with severe acute malnutrition (SAM) using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV).

Study Setting: The study was carried out at the Indira Gandhi Institute of Child Health (IGICH), Bengaluru, a tertiary care referral center for pediatric patients.

Study Period: The study was conducted over 18 months, from July 2023 to December 2024.

Study Population: Children aged 6 to 42 months diagnosed with severe acute malnutrition according to WHO criteria and admitted to the hospital during the study period were screened for eligibility.

Sample Size: The minimum sample size was calculated using the single population proportion formula with an expected proportion of 94.7%, absolute precision of 7%, and 95% confidence level, yielding a required sample size of 39. After considering a 10% dropout rate, the sample size was increased to 43 and rounded off to 50 children.

Inclusion Criteria

- Children aged 6–42 months diagnosed with severe acute malnutrition according to WHO criteria:
- Weight-for-height < −3 SD, or
- Mid-upper arm circumference (MUAC) <11.5 cm, or
- Presence of bilateral nutritional edema.
- Parents or legally authorized representatives willing to provide written informed consent.

Exclusion Criteria

- Parents refusing informed written consent.
- Children with secondary causes of severe acute malnutrition such as:
- Congenital heart disease.
- Malabsorption syndromes.
- Renal dysfunction.
- Neurometabolic disorders.

Methodology: After obtaining informed written consent, eligible children underwent detailed clinical evaluation using a predesigned and pretested proforma. Information regarding demographic characteristics, presenting complaints, birth history, feeding practices, immunization status, developmental milestones, socioeconomic background, and past medical history was recorded. A complete physical examination, anthropometric assessment, and systemic examination were performed.

Baseline laboratory investigations included complete blood count with peripheral smear, serum electrolytes, random blood glucose, urine routine

examination, blood culture, chest radiography, and Mantoux test to exclude secondary causes of malnutrition and associated infections.

All enrolled children received treatment according to the WHO standard protocol for the management of severe acute malnutrition, including stabilization, nutritional rehabilitation, micronutrient supplementation, management of infections, and structured play therapy.

Following stabilization during the rehabilitation phase, neurodevelopmental assessment was performed using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV). Developmental Quotient (DQ) was calculated using the formula:

Developmental Quotient (DQ) = (Age Equivalent ÷ Chronological Age) × 100

A DQ of less than 70 in any developmental domain was considered indicative of developmental delay, while delay involving more than one developmental domain was classified as Global Developmental Delay (GDD).

All children were followed up three months after discharge, during which anthropometric measurements were repeated and neurodevelopment was reassessed using BSID-IV. Developmental Quotient (DQ) and Growth Scale Values (GSV) were compared with baseline measurements to evaluate improvement following nutritional rehabilitation.

Outcome Measures:

Primary Outcome: Assessment of neurodevelopmental status among children with severe acute malnutrition using BSID-IV.

Secondary Outcomes:

- Improvement in Developmental Quotient (DQ) after three months of nutritional rehabilitation.
- Changes in Growth Scale Values (GSV) between baseline and follow-up.
- Identification of children with Global Developmental Delay (GDD).

Statistical Analysis: Data were entered into Microsoft Excel 2016 and analyzed using IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean ± standard deviation. The paired sample t-test was used to compare baseline and three-month follow-up developmental scores. A p-value <0.05 was considered statistically significant.

Ethical Considerations: The study was approved by the Institutional Ethics Committee of the Indira Gandhi Institute of Child Health, Bengaluru. Written informed consent was obtained from the parents or legally authorized representatives of all participating children before enrollment. Patient confidentiality was maintained throughout the study.

RESULTS

A total of 50 children aged 6–42 months with severe acute malnutrition (SAM) were enrolled in the study and assessed using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV) after stabilization and again after three months of nutritional rehabilitation. The demographic profile, developmental status, and changes in developmental outcomes are summarized below.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (n = 50)

Variable	Category	Frequency (n)	Percentage (%)
Age	Up to 12 months	23	46.0
	13–24 months	23	46.0
	>24 months	4	8.0
Gender	Male	25	50.0
	Female	25	50.0
Socioeconomic Status	Lower Middle (Class III)	6	12.0
	Upper Lower (Class IV)	23	46.0
	Lower (Class V)	21	42.0
Mother's Education	Illiterate	1	2.0
	Primary School	32	64.0
	High School	6	12.0
	Intermediate	11	22.0
Adequate Birth Spacing (>2 years)	Yes	12	24.0
	No	23	46.0
	First born/Others	15	30.0

Most children (92%) were younger than 24 months of age, with equal gender distribution. Nearly 88% belonged to lower socioeconomic classes (Class IV and V), and the majority of mothers had only primary education. Nearly half of the children (46%) had inadequate birth spacing, highlighting multiple socioeconomic risk factors associated with severe acute malnutrition.

Table 2: Developmental Profile of SAM Children at Baseline (BSID-IV) (n = 50)

Variable	Frequency (n)	Percentage (%)
Developmental milestones delayed (history)	36	72.0
Appropriate developmental milestones	14	28.0
History of faulty/top feeding	29	58.0

Cognitive DQ <70	16	32.0
Fine Motor DQ <70	21	42.0
Gross Motor DQ <70	35	70.0
Receptive Communication DQ <70	0	0
Expressive Communication DQ <70	0	0

Delayed developmental milestones were present in 72% of children. Gross motor delay was the most common developmental impairment (70%), followed by fine motor delay (42%) and cognitive delay (32%). No child demonstrated developmental delay in receptive or expressive communication domains. More than half of the children (58%) had a history of faulty or top feeding.

Table 3: Comparison of Developmental Quotient (DQ) Before and After Three Months of Nutritional Rehabilitation

Domain	Baseline Mean ± SD	Follow-up Mean ± SD	t-value	p-value
Cognition	73.97 ± 6.96	87.95 ± 3.88	19.202	<0.001
Receptive Communication	89.43 ± 5.13	94.01 ± 3.15	6.907	<0.001
Expressive Communication	88.90 ± 4.75	93.38 ± 2.83	6.986	<0.001
Fine Motor	72.13 ± 8.36	87.95 ± 3.34	14.791	<0.001
Gross Motor	68.97 ± 6.59	87.58 ± 4.07	26.221	<0.001

There was a highly significant improvement in developmental quotient across all BSID-IV domains following three months of nutritional rehabilitation ($p<0.001$). The greatest improvement was observed in the gross motor domain, followed by cognition and fine motor domains, indicating substantial recovery in neurodevelopment after appropriate management.

Table 4: Comparison of Growth Scale Values (GSV) Before and After Three Months of Follow-up

Domain	Baseline Mean ± SD	Follow-up Mean ± SD	t-value	p-value
Cognition	497.96 ± 12.73	507.14 ± 10.41	22.568	<0.001
Receptive Communication	500.74 ± 12.40	507.46 ± 11.58	31.142	<0.001
Expressive Communication	501.76 ± 13.53	509.08 ± 12.30	26.363	<0.001
Fine Motor	498.84 ± 11.70	508.06 ± 9.63	16.334	<0.001
Gross Motor	496.56 ± 15.10	509.88 ± 11.51	16.984	<0.001

Growth Scale Values improved significantly in all developmental domains after nutritional rehabilitation ($p<0.001$). The findings demonstrate measurable developmental gains over the three-month follow-up period, suggesting that early nutritional rehabilitation coupled with developmental stimulation positively influences neurodevelopmental outcomes in children with severe acute malnutrition.

DISCUSSION

Severe acute malnutrition (SAM) is well recognized as a major contributor to impaired neurodevelopment during early childhood. The present study evaluated neurodevelopmental status in children aged 6–42 months with SAM using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV) and demonstrated that developmental delay was most prominent in the gross motor, fine motor, and cognitive domains. Significant improvement in developmental quotient (DQ) and Growth Scale Values (GSV) was observed after three months of nutritional rehabilitation, emphasizing the beneficial effects of early intervention.

In the present study, 32% of children had cognitive developmental delay, while fine motor and gross motor delays were observed in 42% and 70% of children, respectively. These findings are consistent with those reported by Kerac et al., who emphasized that children with SAM frequently exhibit significant neurodevelopmental impairment due to altered brain growth, reduced neuronal connectivity, and delayed motor maturation. Similar observations were reported by Lelijveld et al., who demonstrated persistent neurocognitive deficits and structural brain abnormalities among children recovering from severe acute malnutrition, highlighting the long-term consequences of early nutritional deprivation.[9,10]

Gross motor delay was the most common developmental abnormality observed in our study. This may be attributed to severe muscle wasting, decreased muscle strength, reduced physical activity, and delayed neuromuscular maturation associated with SAM. Comparable findings were reported by Lelijveld et al., who showed that children with SAM exhibit impaired motor performance even after clinical recovery and therefore require continued developmental monitoring and rehabilitation.[11]

Following nutritional rehabilitation, statistically significant improvement was observed in developmental quotients across cognition, receptive communication, expressive communication, fine motor, and gross motor domains. These findings suggest that neurodevelopmental deficits associated with SAM are at least partially reversible when timely nutritional therapy and developmental stimulation are provided. Similar improvements have been described by Isanaka et al., who demonstrated that nutritional rehabilitation significantly improves linear growth and developmental outcomes among children treated for severe acute malnutrition.[12]

The present study also demonstrated significant improvement in Growth Scale Values (GSV) across

all developmental domains during follow-up, indicating continued developmental progress after discharge. These findings are supported by the systematic review conducted by Upadhyay et al., which concluded that structured nutritional rehabilitation combined with developmental stimulation results in better cognitive and motor outcomes among children with SAM compared with nutritional therapy alone.[13]

The management of SAM extends beyond correction of nutritional deficits and should include early developmental assessment and intervention. WHO guidelines recommend integrating psychosocial stimulation, structured play therapy, caregiver education, and follow-up developmental surveillance into routine SAM management. Consistent with these recommendations, children in the present study received standard nutritional rehabilitation along with developmental stimulation, which likely contributed to the observed improvement in developmental outcomes. Similar recommendations have been emphasized by the World Health Organization, which advocates comprehensive rehabilitation to optimize both growth and neurodevelopment.[14]

Our findings are further supported by Taneja et al., who reported that children receiving appropriate nutritional rehabilitation demonstrate substantial improvement in developmental performance during follow-up, although some deficits may persist, particularly among those with prolonged malnutrition before treatment. Likewise, Gladstone et al. highlighted the importance of standardized developmental assessment tools such as BSID for early identification of developmental delay and timely intervention to improve long-term neurological outcomes in children with severe acute malnutrition.[15,16]

Overall, the present study demonstrates that severe acute malnutrition is associated with significant impairment in cognitive and motor development, particularly gross motor function. Early identification using BSID-IV followed by comprehensive nutritional rehabilitation and developmental stimulation results in significant improvement in neurodevelopmental outcomes. These findings support incorporating routine developmental screening and follow-up into standard management protocols for children with severe acute malnutrition.

CONCLUSION

Children with severe acute malnutrition exhibited significant neurodevelopmental impairment, predominantly affecting gross motor, fine motor, and cognitive domains. Assessment using the Bayley Scale of Infant and Toddler Development-IV (BSID-IV) enabled early identification of developmental delays. Following nutritional rehabilitation and standard management, significant improvements were observed in Developmental Quotient (DQ) and Growth Scale Values (GSV) across all developmental domains after three months of follow-up. These findings emphasize that early nutritional intervention combined with developmental stimulation can substantially improve neurodevelopmental outcomes. Routine neurodevelopmental assessment should therefore be incorporated into the management of children with severe acute malnutrition to facilitate timely intervention and improve long-term developmental prognosis.

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