DOI: 10.7860/IJNMR/2025/79386.2452

Original Article

Paediatrics Section

Micronutrient Status and the Predictors of Recovery Time in Children with Severe Acute Malnutrition: A Prospective Observational Study

ANUSHA CHELLADURAI[1], SHIVASHANKARAN SADAGOPAN[2], SENTHIL KUMAR KRISHNAMOORTHY[3]

ABSTRACT

Introduction: Severe Acute Malnutrition (SAM) remains a major cause of child mortality worldwide. Understanding the determinants of recovery time in children with SAM is pivotal for reducing associated mortality and morbidity. The significance of this study stems from investigating whether recovery duration in this population could be shortened by elucidating the roles of micronutrients and other multifactorial influences, including clinical and demographic characteristics before hospitalisation and during inpatient care.

Aim: To determine the median time to recovery and the factors associated with time to recovery, and to assess the prevalence of micronutrient deficiency and the complications experienced by children under five with SAM during hospitalisation.

Materials and Methods: A prospective observational study was conducted from September 2021 to September 2022, involving 130 children at the Nutritional Rehabilitation Centre (NRC), Institute of Child Health and Hospital for Children, Chennai, Tamil Nadu, India, with SAM, aged from the post neonatal period up to 59 months, of both sexes. The clinical status, anthropometry, co-morbidities, treatment, feed increments, duration of hospital stay, and complications during the stay were assessed and recorded. Laboratory assessment of serum micronutrient levels at admission was performed. The children were followed for 15 days to determine time to recovery as per World Health Organisation (WHO) guidelines. Multivariate logistic regression analysis was performed to identify factors associated with faster recovery (defined as a recovery time shorter than the median). International Business Machines Statistical Package for the Social Sciences (IBM SPSS) version 21 was used for statistical analysis.

Results: The median recovery time was 19.5 days. Factors strongly associated with faster recovery in SAM children included a hospital stay of less than two weeks, oedema at presentation, a caloric intake of ≥120 kcal/kg/day at discharge, and normal serum copper levels. The overall prevalence of micronutrient deficiency in the study group was 84.6%, with deficiencies in magnesium (n=99, 76.2%), zinc (n=70, 53.8%), iron (n=54, 41.5%), and copper (n=33, 25.4%).

Conclusion: Low serum micronutrient values were associated with longer hospital stays, highlighting the importance of micronutrient supplementation during stabilisation and rehabilitation of children with SAM. Special emphasis should be placed on preventing co-morbidities to achieve faster recovery. Policy efforts should focus on community-based treatment, which is essential for achieving faster recovery in the inpatient management of SAM in children.

Keywords: Child nutritional disorders, Micronutrients deficiency, Nutritional status, Recovery of function, Severe acute malnutrition

INTRODUCTION

Severe Acute Malnutrition (SAM) remains a major cause of child mortality worldwide. While pneumonia and diarrhoea are often part of the causal pathway, severe wasting is estimated to account for about 400,000 child deaths each year [1]. Micronutrient deficiency is a major contributor to childhood morbidity and mortality [2]. SAM has both immediate and long-term nutritional consequences, including a decreased Intelligence Quotient (IQ) and stunted growth [3]. SAM is defined as weight-for-height z-score ≤ -3 according to the WHO growth standards, or a Mid-upperarm Circumference (MUAC) <115 mm, or the presence of bilateral oedema in children aged 6-59 months [4]. SAM in infants aged 0-5 months is defined as weight-for-length z-score < -3 or the presence of bilateral pitting oedema [4].

In a retrospective cohort analysis, the median recovery time in SAM children was 15 days, and the nutritional recovery rate was 81.3% [5]. The presence of atleast one co-morbidity (e.g., pneumonia, stunting, shock, and deworming), as well as age, daily weight gain per kilogram of body weight, and vaccination status, was found to be significant independent predictors of nutritional recovery time [5].

Copper, zinc, iron, and magnesium are essential micronutrients for nutritional recovery. Copper deficiency can cause myelopathy, peripheral neuropathy, and optic neuropathy, among other neurological issues [6]. Zinc is essential for growth and immune function, and its supplementation promotes tissue synthesis and nitrogen metabolism, resulting in a healthier body composition [7,8]. A subgroup analysis from a meta-analysis reported a net gain in length (cm) with a dose of 10 mg zinc/day for 24 weeks, leading to a mean gain of 0.37±0.25 cm in the zinc-supplemented group compared with placebo [8].

A significant incidence of severe anaemia in SAM, with a substantial proportion (25%) requiring blood transfusion, suggests that nutritional anaemia is an important co-morbidity of SAM that necessitates hospitalisation [9], with microcytic anaemia being most common (38.6%) and megaloblastic anaemia (30.5%) [9]. Magnesium is required for membrane stability, nerve transmission, ion transport, and calcium channel activity [10]. Only a substantial increase in Mg2+ supply may contribute to catch-up growth and recovery from malnutrition [11,12]. Multiple micronutrient deficiencies are common in many settings, necessitating the development of convenient methods for assessing and treating multiple deficiencies. The true prevalence of these deficits in children with SAM remains unknown due to data gaps.

Although the metabolism of Fe, Cu, and Zn is closely intertwined, few publications evaluate all three minerals [13,14]. Even the micronutrient updates in the fourth report of the World Nutrition Situation acknowledge that micronutrient deficiencies have not been adequately addressed [15]. There is a need for better data on micronutrient deficiencies at national and subnational levels [1]. Hence, this study aimed to determine the median time to nutritional recovery and the factors affecting recovery time, to assess the prevalence of micronutrient deficiency and the complications faced by children under five with SAM during hospitalisation, and to improve the management of SAM, which is an integral part of the WHO infant and young child nutrition initiatives, with the goal of reducing the global burden of disease [3].

MATERIALS AND METHODS

This prospective observational study was conducted from September 2021 to September 2022 at the Nutritional Rehabilitation Centre (NRC), Institute of Child Health and Hospital for Children, Chennai, Tamil Nadu, India, which is regarded as the main referral hospital for nutritional rehabilitation. The study received clearance from the Ethics Committee (IEC No. 31102020, dated 21 October 2020) at Madras Medical College (MMC), Chennai. Informed consent was obtained from the parent or guardian. Strict confidentiality was maintained in the analysis and presentation of the data.

Sample size calculation: The study included 130 children diagnosed with Severe Acute Malnutrition (SAM). Adjusting for an anticipated 10% loss to follow-up, the sample size was calculated as:

$$n = Z^2_{1-\alpha/2}\, p\,(1-p)/d^2$$

Here, 'p' is the expected proportion, d is the absolute precision, and 1-α/2 is the desired confidence level.

Expected proportion of Nutritional Recovery [5] -81.3%

Precision -7%

Desired confidence level (1-alpha)-95%

Hence, the required sample size is 119.

Inclusion criteria:

- Children from the post neonatal period up to 59 months of age with SAM, as defined by [4];
- For 0-5 months: weight-for-length z-score <-3 or presence of bilateral pitting oedema;
- For 6-59 months: weight-for-length/height z-score <-3, or MUAC <115 mm, or bilateral oedema;
- Sex: all eligible;
- Caregiver willing to provide consent for enrollment and to stay connected for about 15 days post Inpatient Department treatment;
- All these children admitted to the NRC at the Institute of Child Health and Hospital for Children, Chennai.

Exclusion criteria:

- Symmetrical Intrauterine Growth Retardation (IUGR) babies;
- Children with dysmorphic facies;
- Children known to have genetic disorders;
- SAM children whose parents did not consent to participate in the study.

Supervised nutritional therapy [16]:

- About 8-12 small F75 feeds were given daily to deliver 130 mL/kg, 100 kcal/kg, and 1-1.5 g protein/kg; for those who were breastfeeding, breastfeeding was continued.
- The quantity was reduced to 100 mL/kg/day if there is extensive oedema.
- A 24 hour intake log was maintained, and the feeds were carefully measured.
- The child was encouraged to finish the meal; if more than 80% of the provided amount remained, an NG tube was used to provide feeds.
- F100 was switched from F75 when appetite recovered and oedema diminished.
- The child was weighed daily, and weight gain was tracked.
- For clinically stable SAM children, daily basic calorie and protein requirements were calculated and gradually increased to the maximum tolerable quantity toward recovery.

Study Procedure

Clinical Data Collection

All eligible children meeting the defined criteria were recruited up to September 2022 after obtaining consent from the parent/guardian, using a standard data-extraction form; information was abstracted in detail. A complete evaluation of each patient, including a detailed history, clinical examination, and necessary investigations, was performed. At presentation, the symptoms that brought the child to the hospital and signs of deficiency were recorded. During hospitalisation, data on the need for oxygen, inotropes, or antibiotics; the day of initiation of feeds in critically ill SAM children; the progression of feeds; and the pattern of weight gain were studied. An important aspect noted was whether they acquired nosocomial infections during the stay. Samples collected at admission were processed to determine serum levels of iron, zinc, magnesium, and copper to study the prevalence of micronutrient deficiency. After discharge, the child was followed for 15 days, and recovery time, in terms of weight gain and other signs of recovery as per Facility-based Integrated Management of Neonatal and Childhood Illness (F-IMNCI) guidelines [17], was studied and analysed during follow-up.

Primary and secondary outcomes:

- The primary outcome was the duration of recovery and the prevalence of micronutrient deficiency among the study population.
- The secondary outcomes were the incidence and severity of diarrhoea, pneumonia, septic shock, Urinary Tract Infection (UTI), meningitis, and electrolyte abnormalities in children with SAM during inpatient treatment, and the factors associated with predicting recovery time in hospitalised SAM children.

Definition of recovery: Recovery was defined as meeting the following criteria during the hospital stay or during the 15 day follow-up after discharge [18]:

- Return of appetite, consuming at least 120-130 kcal/kg/day and receiving adequate micronutrients
- Disappearance of oedema
- Consistent weight gain (at least 5 g/kg/day for three consecutive days)
- All infections and other conditions (e.g., anaemia, diarrhoea, malaria, tuberculosis) have been treated, and antibiotic therapy completed
- Full immunisation programme started or completed as appropriate for age

Sample collection and Laboratory methods: Under sterile precautions, blood samples were collected from the study population (n=130) on the day of admission. About 2 mL of venous blood was drawn and transferred to a tube containing a clot activator. The clotted blood was centrifuged at 3,000 rpm for 10 minutes. The serum separated was then transferred to 1.5 mL capacity plastic microcentrifuge tubes and stored at –20°C until required for the processing of serum levels of iron, magnesium, zinc, and copper. Assessment was performed using a flame spectrophotometer in the biochemistry laboratory. Final values of iron, copper, and zinc were expressed in µg/dL [18]. Serum magnesium was expressed in mg/dL [18]. Cut-off values were determined according to the laboratory reference ranges.

STATISTICAL ANALYSIS

Descriptive analysis was performed using means and standard deviations for quantitative variables, and frequencies and proportions for categorical variables. Data were also represented using diagrams such as bar charts and pie-charts. The association between hospital stay, outcome, and various categorical variables was assessed by cross-tabulation and comparison of percentages. The Chi-square test was used to test statistical significance. The median time to recovery was 19.5 days in this study, in line with similar studies [19-21], and faster recovery was defined as less than 20 days in the study population. Multivariate logistic regression analysis was performed to test the association between the factors listed in [Table/Fig-1-4] and recovery within 20 days. Adjusted odds ratios with their 95% confidence intervals were presented. A p-value <0.05 was considered statistically significant. IBM SPSS Statistics, version 21, was used for statistical analysis.

RESULTS

[Table/Fig-1] provides an outline of the presenting symptoms and clinical features at admission in the study group (N=130). Key characteristics include the most common age group being 7-24 months, with females more numerous than males and rural residents more numerous than urban residents. Fever and watery diarrhoea were the most common presenting illnesses. About 91 children (70%) were admitted weighing less than 7 kg; 125 (96.2%) presented with wasting, while 5 (3.8%) had nutritional oedema. Clinical pallor was observed in about 100 children (76.9%). Only two children (1.5%) presented with a flag sign, seven children (5.4%) with skin excoriation, and 4 (3.1%) with shock. Furthermore, about 31 (23.8%) were already on antibiotics, and 41 (31.5%) were already receiving nutritional supplements.

Variables		Frequency (N=130)	Percentage
Child's age	0-6 months	29	22.3%
	7-11 months	35	26.9%
	12-24 months	35	26.9%
	25-36 months	11	8.5%
	37-59 months	20	15.4%
Gender	Male	57	43.8%
	Female	73	56.2%
Residence	Rural	80	61.5%
	Urban	50	38.5%
Admission type	New admission	124	95.4%
	Re admission	6	4.6%
Symptomatology	Cough	45	34.6%
	Fever	72	55.4%
	Fast breathing	43	33.1%
	Vomiting	44	33.8%
	Diarrhea (watery)	56	43.1%
	Diarrhea (bloody)	1	0.8%
	Dehydration	21	16.2%
	Convulsion	14	10.8%
Duration of diarrhea	Absent	73	56.2%
	Acute	52	40%
	Persistent	5	3.8%
Breastfeeding upto 6 months	No	24	18.5%
	Yes	106	81.5%
Contact with open case of tuberculosis (TB)	No	125	96.2%
	Yes	5	3.8%
Dewormed	No	37	28.55
	Yes	21	16.2%
	Not applicable (11 months)	72	55.4%
Immunisation	Not immunised	4	3.1%
	Partially immunised	21	16.2%
	Fully immunised	105	80.8%
Co-morbidities	Nil	15	11.5%
	Anemia	83	63.8%
	TB	3	2.3%
	Congenital Heart Disease (CHD)	7	5.4%
	Global developmental delay	19	14.6%
	Cerebral palsy	3	2.3%
Admission weight	<7 kg	91	70%
	>7 kg	39	30%
Triceps skin fold thickness	Normal for age	56	43.1%
	<-3 standard deviation	67	51.5%
	Not applicable (<3 months)	7	5.4%
Head circumference for age	Normal for age	111	85.4%
	<-3 standard deviation	19	14.6%
Clinical form of SAM	Oedema	5	3.8%
	Wasted	125	96.2%

Sensorium	Alert	62	47.7%
	Lethargic	68	52.3%
Temperature at the time of admission	Normal	85	65.4%
	Febrile	40	30.8%
	Hypothermia	5	3.8%
Pallor	Absent	30	23.1%
	Present	100	76.9%
Lymphadenopathy	Absent	124	95.4%
	Cervical	3	2.3%
	Axillary	3	2.3%
Skin changes	Absent	83	63.8%
	Hypopigmentation	31	23.8%
	Hyperpigmentation	9	6.9%
	Excoriation	7	5.4%
Hair changes	Absent	101	77.7%
	Hypopigmented	27	20.8%
	Flag sign	2	1.5%
Skeletal changes	Absent	122	93.8%
	Present	8	6.2%
Ear discharge	Absent	127	97.7%
	Present	3	2.3%
Shock	No	126	96.9%
	Yes	4	3.1%
Cardiovascular system findings	Normal	89	68.5%
	Tachycardia	19	14.6%
	Murmur	22	16.9%
Respiratory system findings	Normal	79	60.8%
	Tachypnea	40	30.8%
	Crepitations	11	8.5%
Organomegaly	Absent	108	83.1%
	Hepatomegaly	17	13.1%
	Splenomegaly	5	3.8%
Neurological deficit	Absent	121	93.1%
	Present	7	5.4%
	Microcephaly	2	1.5%
Already on antibiotics	No	99	76.2%
	Yes	31	23.8%
Already on	No	89	68.5%

[Table/Fig-1]: Clinical and demographic characteristics of the study group (N=130).

[Table/Fig-2] depicts the serological presentations in the study group, from most to least common, highlighting the changes in laboratory parameters in children with SAM.

[Table/Fig-3] shows the treatment outcomes in children with SAM, underscoring the need for personalised management strategies. Of the study group, 98 children (75.4%) recovered, 30 (23.1%) were non responders, and 2 (1.5%) died. Additionally, about 39 (30%) of these children required a hospital stay of more than two weeks.

[Table/Fig-4] presents the percentage of children in the study group (N=130) exhibiting low serum levels of iron, magnesium, copper, and zinc at admission. A higher prevalence of low serum magnesium and zinc levels was observed. The median time to recovery was 19.5 days. This was in line with similar studies [19-21], and thus faster recovery was defined as less than 20 days in the study population. All factors deemed relevant by the literature review were included in the multivariate analysis. As shown in [Table/Fig-5], the multivariate logistic regression analysis revealed statistically significant associations with recovery time of less than 20 days across several explanatory factors. The strongest association was observed with a duration of hospital stay <2 weeks (OR=13.8, 95% CI: 2.0-95.0, p=0.001). Other significant associations included the clinical form of SAM (edema) (OR=0.49, 95% CI: 0.08-2.7, p=0.001), calories taken at discharge >120 kcal/kg/day (OR=0.5, 95% CI: 0.29-1.15, p=0.04), and normal levels of serum copper (OR=0.73, 95% CI: 0.49-1.09, p=0.03). [Table/Fig-6] indicates a significant association between complications and duration of hospital stay. Of the children who stayed less than a week, 39 (76.6%) had no complications.

Variables		Frequency (N=130)	Percentage
Capillary blood glucose at admission	Normal	116	89.2%
	Hypoglycaemia	14	10.8%
Total White Blood Cell (WBC) count	Normal	52	40%
	Neutrophilia	51	39.2%
	Neutropenia	27	20.8%
Haemoglobin	Normal for age	24	18.5%
	Low	106	81.5%
Platelet count	Normal	87	66.9%
	Thrombocytopenia	3	2.3%
	Thrombocytosis	40	30.8%
Renal function test	Normal	113	86.9%
	Raised	17	13.1%
Liver function test	Normal	103	79.2%
	Raised	27	20.8%
Serum sodium	Normal	86	66.2%
	Hyponatremia	42	32.3%
	Hypernatremia	2	1.5%
Serum potassium	Normal	128	98.5%
	Hypokalemia	2	1.5%
Serum total protein	Normal	111	85.4%
	Low	19	14.6%
Serum albumin	Normal	105	80.8%
	Low	25	19.2%
Serum calcium	Normal	118	90.8%
	Hypocalcemia	12	9.2%
Micronutrient deficiency	Absent	20	15.4%
	Present	110	84.6%
Radiological findings (chest X-ray)	Normal	80	61.5%
	Pneumonia	33	25.4%
	Cardiomegaly	17	13.1%
Blood culture	No growth	103	79.2%
	Pathogenic growth	27	20.8%
Urine culture	No growth	122	93.8%
	Pathogenic growth	8	6.2%
Radiological findings in Ultrasonography (USG) Abdomen	Normal	122	93.8%
	Hepatosplenomegaly	6	4.6%
	Altered echoes in kidneys	2	1.5%
Cerebrospinal Fluid (CSF) study	Normal	122	93.8%
	Suggestive of meningitis	8	6.2%

[Table/Fig-2]: Laboratory parameters in the study group (N=130), on admission.

Variables		Frequency (N=130)	Percentage
Day of starting oral feeds	<3 days of admission	120	92.3%
	>3 days of admission	10	7.7%
Increment of oral feeds	Successful in <5 days	117	90%
	Not successful	13	10%
Use of formula 75 (F75)	Not needed	46	35.4%
	Yes	84	64.6%
Use of Ready to Use Therapeutic Food (RUTF)	No	43	33.1%
	Yes	87	66.9%
Use of resomal	Not required	88	67.7%
	Yes	42	32.3%
Return of appetite	≤3 days	120	92.3%
	>3 days	10	7.7%
Supportive therapy	Not required	71	54.6%
	Mechanical ventilation	4	3.1%
	Intravenous Fluids (IVF) maintenance	16	12.3%
	O_2 (prongs/Non Rebreather Mask (NRM)), IVF	30	23.1%
	O_2 through High Flow Nasal Cannula (HFNC), IVF	9	6.9%
Use of ionotropes	Not required	124	95.4%
	Required <2 days	6	4.6%
Requirement of antibiotics	Not required	26	20%
	Oral	4	3.1%
	IV	100	76.9%
Complications	Nil	73	56.2%
	Severe sepsis	31	23.8%
	Bronchopneumonia	19	14.6%
	Severe dehydration	5	3.8%
	Death	2	1.5%
Weight gain	<5 g/kg/day	17	13.1%
	≥5 g/kg/day	39	30%
	>8 g/kg/day	74	56.9%
Mid-upperarm Circumference (MUAC) gain	<0.24 mm/day	48	36.9%
	>0.24 mm/day	82	63.1%
Disappearance of oedema	Not applicable (wasted)	125	96.2%
	≤5 days	2	1.5%
	>5 days	3	2.3%
Calories taken at discharge	<100/kg/day	1	0.8%
	100-120/kg/day	40	30.8%
	≥120 kg/kg/day	89	68.5%
Protein consumed at discharge	<2 g/kg/day	14	10.8%
	≥2 g/kg/day	116	89.2%
Outcome	Recovered	98	75.4%
	Non response	30	23.1%
	Death	2	1.5%
Duration of hospital stay	<1 week	49	37.7%
	1-2 weeks	42	32.3%
	≥2 weeks	39	30%
Hospital acquired infections	No	76	58.5%
	Pneumonia	27	20.8%
	Sepsis	16	12.3%
	Urinary Tract Infection (UTI)	11	8.5%

[Table/Fig-3]: Management strategy in the study group (N=130).

Micronutrients		Frequency (%)
Serum iron	Normal	76 (58.9%)
	Low	54 (41.5%)
Serum magnesium	Normal	31 (23.8%)
	Low	99 (76.2%)
Serum copper	Normal	97 (74.6%)
	Low	33 (25.4%)
Serum zinc	Normal	60 (46.2%)
	Low	70 (53.8%)

[Table/Fig-4]: Prevalence of micronutrient deficiency.

Factors	Total recovered	N (%)	Odds ratio	95% CI	p-value
Age <24 months	28	14 (50%)	1.00	0.64-1.55	0.91
Gender-Female	56	27 (48.2%)	1.08	0.73-1.61	0.11
Residence urban	38	21 (55.3%)	0.84	0.57-1.25	0.47
Cough	33	12 (36.4%)	1.5	0.95-2.5	0.06
Fever	53	29 (54.7%)	0.81	0.54-1.22	0.06
Fast breathing	30	9 (30%)	1.9	1.09-3.5	0.40
Vomiting	35	24 (68.6%)	0.57	0.39-0.84	0.19
Diarrhoea Watery	45	27 (60%)	0.69	0.46-1.03	0.097
Admission weight >7 kg	35	19 (54.3%)	0.87	0.58-1.30	0.78
Dewormed-Yes	20	12(60%)	0.96	0.64-1.42	0.12
Triceps skin fold thickness <-3 standard deviation	47	18 (38.3%)	0.63	0.41-0.96	0.83
Clinical form of SAM oedema	4	1 (25%)	0.49	0.08-2.70	0.001
Calories taken at discharge ≥120/day	79	43 (54.4%)	0.58	0.29-1.15	0.04
Full Immunisation	85	43 (50.6%)	0.91	0.48-1.7	0.80
Haemoglobin-low	79	39 (49.4%)	1.0	0.65-1.72	0.96
Iron normal	63	37 (58.7%)	1.71	1.03-2.8	0.71
Magnesium low	69	33 (47.8%)	1.15	0.76-1.73	0.79
Serum copper normal	74	34 (45.9%)	0.73	0.49-1.09	0.039
Serum zinc normal	53	30 (56.6%)	1.34	0.88-2.03	0.49
Duration of hospital stay <2 weeks	76	48 (63.2%)	13.8	2.0-95.0	0.001

[Table/Fig-5]: Factors associated with days of recovery <20 in study population (multivariate logistic regression analysis).

DISCUSSION

About 98 children (75.4%) recovered during the study; 30 children (23.1%) did not recover, and 2 children (1.5%) died. The median recovery time was 19.5 days. This result was longer than those reported from Pawi (14 days) [22] and Bahir Dar (16 days) [23], but shorter than that of a multicenter study conducted in Rajasthan, Delhi, and Tamil Nadu (5 weeks) [24]. The finding is in line with studies conducted in rural areas of Ethiopia, such as Yirgalem (18.6 days)

Complications	<1 week	1-2 week	≥ 2 weeks	Total
Nil	39 (76.6%)	24 (57.1%)	10 (25.6%)	73 (56.2%)
Severe sepsis	1 (2%)	12 (28.6%)	18 (46.2%)	31 (23.8%)
Bronchopneumonia	4 (8.2%)	6 (14.3%)	9 (23.1%)	19 (14.6%)
Severe dehydration	5 (10.2%)	0 (0%)	0 (0%)	5 (3.8%)
Death	0 (0%)	0 (0%)	2 (5.1%)	2 (1.5%)
Total	49 (100%)	42 (100%)	39 (100%)	130 (100%)

[Table/Fig-6]: Comparison of complications developed during stay across duration of hospital stay (N=130).
Chi-square test: 45.81; p-value: <0.001 (Significant)

[20], Ayder Referral Hospital (21 days) [19], and Jimma (21 days) [21]. In this study, the proportion of female participants was higher (56.2%) than that of males. This was also found in other studies [23, 25, 26]. In contrast, several other studies showed that male gender had higher odds and was found to be at greater risk for SAM [20, 22, 24, 27].

In this study, among the 130 children, 31 (23.8%) had severe sepsis, 19 (14.6%) had bronchopneumonia, and 5 (3.8%) had severe dehydration. The most common comorbid condition observed was anaemia, in 83 children (63.8%). This was consistent with a study conducted in Gujarat, India, which also concluded that the most common co-morbidity in children with SAM was anaemia (75.3% of the study group), but it did not affect the outcome of treatment [28]. Additionally, 19 children (14.6%) had global developmental delay, 7 (5.4%) had congenital heart disease (CHD), about 3 (2.3%) had tuberculosis, and 3 (2.3%) had cerebral palsy. In contrast, a study by Saurabh K et al., showed that the most prevalent co-morbidities were diarrhoea (34.7%) and respiratory tract infection (31.33%) [29]. Tuberculosis was found in 20% of their study group, whereas measles was found in 6.7%.

In the study population, 54 children (41.5%) had iron deficiency, 99 (76.2%) had magnesium deficiency, only 33 (25.4%) had copper deficiency, and 70 (53.8%) had zinc deficiency. When atleast one micronutrient deficiency was considered, about 84.6% of the study population had a micronutrient deficiency. Specifically, 99 children (76.2%) had low serum magnesium levels relative to age-specific cut-offs, indicating the need to include magnesium supplementation in the management of children with SAM. In contrast, in the prospective observational study done by Hother AL et al., which included 72 children with SAM, only about nine children (13%) had serum magnesium values below the age-specific cut-off at the time of admission [30].

Overall, it was observed that the prevalence of low serum magnesium and serum zinc levels was higher than that of the other micronutrients measured in this study. A general gap in addressing the prevalence of micronutrient deficiency exists in the global literature [1]. Therefore, this study emphasises that a normal micronutrient status is linked to a recovery time of less than 20 days. Interestingly, children presenting with oedema were associated with a reduced likelihood of rapid recovery (OR = 0.49, 95% CI: 0.08-2.7, P=0.001). This aligns with findings from multiple observational studies in Southern Ethiopia, where children with oedema (kwashiorkor) often demonstrated a slower resolution of clinical signs compared to those with marasmus [31-33]. While edematous children might appear more clinically severe at admission, their response to therapeutic feeding was often slower until stabilisation. Adequate caloric intake at discharge (>120 kcal/kg/day) was also significantly associated with early recovery (OR=0.5, 95% CI: 0.29-1.15, P=0.04). This finding reinforced WHO recommendations for energy-dense therapeutic diets and mirrored programmatic experiences in Indian Nutritional Rehabilitation Centres, where energy intake of 120-130 kcal/kg/day has been a key recovery benchmark [34].

An important and less commonly explored factor in this study was the association between normal serum copper levels at admission and faster recovery (OR=0.73, 95% CI: 0.49-1.09, P=0.03). Although micronutrient deficiencies, including copper, are prevalent in children with SAM, only a few studies have assessed their direct influence on recovery time [14, 35]. These results suggest that adequate copper status might play a role in the immune and enzymatic functions necessary for efficient rehabilitation. This novel association warrants further investigation. The key strength of this study was that it was one of the few in India specifically focusing on treatment outcomes, factors affecting recovery time, and their association with serum micronutrient levels. This highlighted the importance of anticipating outcomes based on clinical examination, laboratory findings, and treatment response.

Limitation(s)

The study had the following limitations: Due to logistical reasons, recovery time was calculated based on a short follow-up period of 15 days after discharge. Additionally, the long-term response to micronutrient supplementation, in terms of both clinical recovery and serum levels, was not assessed in this study. Future analytical studies with larger sample sizes could provide further insights into the impact of micronutrient supplementation on recovery time.

CONCLUSION(S)

The median time of recovery in the study population was 19.5 days. Factors strongly associated with faster recovery (less than the median time of recovery) in a child with SAM included a hospital stay of less than two weeks, clinical presentation with edema, consumption of 120 kcal/kg/day or more at discharge, and normal micronutrient status (specifically copper). The most common medical complications affecting children with SAM were sepsis, bronchopneumonia, and severe dehydration; all of these showed a significant association with time to recovery. The overall prevalence of micronutrient deficiency was 84.6%, with specific rates for magnesium (76.2%), zinc (53.5%), iron (41.5%), and copper (25.4%). Their low serum values were associated with a longer hospital stay, emphasizing the importance of micronutrient supplementation during the stabilization and rehabilitation of children with SAM. Policies should focus on community-based treatment, which is essential to achieving faster recovery in the inpatient management of SAM.

Acknowledgement

It is with immense pleasure and privilege that we express our heartfelt gratitude and admiration for the invaluable help and guidance received from Dr. S. Srinivasan, DCH, State Child Health Nodal Officer and In-Charge of the NRC, Institute of Child Health and Hospital for Children. His support was instrumental at every stage of this study, and we are grateful for the significant opportunity to conduct this research at NRC, Chennai, under his esteemed guidance.

Our sincere thanks go to Prof. Dr. S. Elilarasi, MD, DCH, Professor and Head of the Department of Paediatrics, for her unwavering guidance and support throughout this study. We are profoundly indebted to our guide and teacher, Prof. Dr. D. Anuradha, MD, DCH, PhD, Professor of Paediatrics, for her exceptional supervision, guidance, and continuous encouragement while undertaking this study.

Our heartfelt thanks are extended to Prof. Dr. K. Pramila, MD, the Head of the Department of Biochemistry, for her assistance in processing samples and ensuring the accuracy of reports.

We wish to thank the respected Dean, Dr. E. Theranirajan, MD, DCH, MRCPCH, FRCPCH, and the members of the Ethical Committee at Rajiv Gandhi Government General Hospital and Madras Medical College, Chennai, for granting us permission to conduct this study.

Finally, we extend our deepest gratitude to all the parents and children who voluntarily participated in this study. Without their invaluable contribution, this research would not have been possible.

REFERENCES

[1] Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low- and middle-income countries. Lancet. 2013;382:427-51.
[2] Central Statistical Agency (CSA) (Ethiopia) and ICF International. Ethiopia Demographic and Health Survey 2011. Calverton, MD: ICF International; 2012. p. 175.
[3] World Health Organization. Guideline: Updates on the management of severe acute malnutrition in infants and children. Geneva: WHO; 2013.
[4] World Health Organization. Guideline on the prevention and management of severe acute malnutrition in infants and children. Geneva: WHO; 2013. pp. 19-20, 63.
[5] Adimasu M, Sebsibie G, Abebe F, Baye G, Abere K. Recovery time from severe acute malnutrition and associated factors among under-5 children in Yekatit 12 Hospital, Addis Ababa, Ethiopia: a retrospective cohort study. Epidemiol Health. 2020;42:e2020003.
[6] Jaiser SR, Winston GP. Copper deficiency myelopathy. J Neurol. 2010;257(6):869-81.
[7] Schlesinger L, Arevalo M, Arredondo S, Diaz M, Lonnerdal B, Stekel A. Effect of zinc-fortified formula on immunocompetence and growth of malnourished infants. Am J Clin Nutr. 1992;56(4):491-98.
[8] Imdad A, Bhutta ZA. Effect of preventive zinc supplementation on linear growth in children under 5 years of age in developing countries: a meta-analysis of studies for input to the Lives Saved Tool. BMC Public Health. 2011;11(Suppl 3):S22.
[9] Thakur N, Chandra J, Pemde H, Singh V. Anemia in severe acute malnutrition. Nutr. 2014;30(4):440-42. Doi: 10.1016/j.nut.2013.09.011.
[10] Weisinger JR, Font EB. Magnesium and phosphorus. Lancet. 1998;352:391-96.
[11] Singla PN, Chand P, Kumar A, Kacchawaha JS. Serum magnesium levels in protein-energy malnutrition. J Trop Pediatr. 1998;44:117-19.
[12] Nichols BL, Alvarado J, Hazlewood CF, Viteri F. Magnesium supplementation in protein-calorie malnutrition. Am J Clin Nutr. 1978;31(1):176-88.
[13] Bebars GM, Afifi MF, Mahrous M, Okaily NE, Mounir SM, Ali E. Assessment of some micronutrient serum levels in children with severe acute malnutrition with and without cerebral palsy- A follow-up case study. Clin Nutr Exp. 2019;23:34-43.
[14] Weisstaub G, Medina M, Pizarro F, Araya M. Copper, iron, and zinc status in children with moderate and severe acute malnutrition recovered following WHO protocols. Biol Trace Elem Res. 2008;124(1):1-11.
[15] United Nations Sub-Committee on Nutrition. Fourth Report on the World Nutrition Situation. Geneva: ACC/SCN and IFPRI; 2000. p.121.
[16] Nelson WE. Nutrition, food security and health. In: Ashworth A, Nelson Textbook of Pediatrics. 21st ed. Amsterdam: Elsevier; 2019:340. Table 57.8.
[17] Ministry of Health and Family Welfare (MoHFW). Facility-Based Integrated Management of Neonatal and Childhood Illness (F-IMNCI). Participants' Manual. New Delhi: MoHFW; 2009. pp. 167-68.
[18] Kleiman K, McDaniel L, Molly M. The Harriet Lane Handbook. 22nd ed. Philadelphia: Elsevier; 2021. pp. 642-50.
[19] Tirore MG, Atey TM, Mezgebe HB. Survival status and factors associated with treatment outcome of severely malnourished children admitted to Ayder Referral Hospital: a cross-sectional study. BMC Nutr. 2017;3:66.
[20] Kabeta A, Bekele G. Factors associated with treatment outcomes of under-five children with severe acute malnutrition admitted to the therapeutic feeding unit of Yirgalem Hospital. Clin Mother Child Health. 2017;14:261.
[21] Misganaw C, Mesfin M, Tesfaye M, Derese A. Retrospective study on outcome of in-patient treatment of severe acute malnutrition in Jimma University Specialized Hospital from September 2011-September 2012. J Diagn. 2014;1(1):18-27.
[22] Wondim A, Tigabu B, Kelkay MM. Time to recovery from severe acute malnutrition and its predictors among admitted children aged 6-59 months at the Therapeutic Feeding Center of Pawi General Hospital, Northwest Ethiopia: a retrospective follow-up study. Int J Pediatr. 2020;2020:8406597. Doi: 10.1155/2020/8406597.
[23] Asres DT, Prasad RPCJ, Ayele TA. Recovery time and associated factors of severe acute malnutrition among children in Bahir Dar city, Northwest Ethiopia: an institution-based retrospective cohort study. BMC Nutr. 2018;4:17. Doi: 10.1186/s40795-018-0224-0.
[24] David SM, Ragasudha PN, Taneja S, Taneja S, Mohan SB, Iyengar SD, et al. Predictors of recovery in children aged 6–59 months with uncomplicated severe acute malnutrition: a multicentre study. Public Health Nutr. 2021;24(15):4899-907.
[25] Atnafe B, Roba KT, Dingeta T. Time of recovery and associated factors of children with severe acute malnutrition treated at outpatient therapeutic feeding program in Dire Dawa, Eastern Ethiopia. PLoS One. 2019;14(6):e0217344.
[26] Shukla Y, Tiwari R, Kasar PK, Tomar SP. Risk factors for severe malnutrition in under-five children admitted to nutritional rehabilitation centre: a case-control study from Central India. Int J Community Med Public Health. 2016;3(1):121-27.
[27] Bhadoria AS, Kapil U, Bansal R, Pandey RM, Pant B, Mohan A. Prevalence of severe acute malnutrition and associated sociodemographic factors among children aged 6 months–5 years in rural population of Northern India: A population-based survey. J Family Med Prim Care. 2017;6(2):380-85.
[28] Shah S, Prajapati N. Anaemia among SAM children and its effect on outcome in nutritional rehabilitation centre at tertiary care centre of Gujarat. Med Pulse Int J Pediatr. 2020;16(2):21-24.
[29] Saurabh K, Ranjan S, Narayan JP. Co-morbidities and micronutrient deficiencies in children with severe acute malnutrition. Int J Contemporary Pediatr. 2017;4(4):1225-27.
[30] Hother AL, Girma T, Rytter MJ, Abdissa A, Ritz C, Mølgaard C, et al. Serum phosphate and magnesium in children recovering from severe acute undernutrition in Ethiopia: an observational study. BMC Pediatr. 2016;16(1):178.
[31] Mengesha MM, Deyessa N, Tegegne BS, Dessie Y. Treatment outcome and factors affecting time to recovery in children with severe acute malnutrition treated at outpatient therapeutic care program. Glob Health Action. 2016;9:30704.
[32] Teshome G, Bosha T, Gebremedhin S. Time-to-recovery from severe acute malnutrition in children 6–59 months of age enrolled in the outpatient treatment program in Shebedino, Southern Ethiopia: a prospective cohort study. BMC Pediatr. 2019;19:1.
[33] Teferi E, Lera M, Sita S, Bogale Z, Datiko DG, Yassin MA. Treatment outcome of children with severe acute malnutrition admitted to therapeutic feeding centers in Southern Region of Ethiopia. Ethiop J Health Dev. 2010;24(3):234-38.
[34] Ministry of Health and Family Welfare (Government of India). Operational guidelines for the management of severe acute malnutrition (SAM). New Delhi: MoHFW; 2011. p. 53.
[35] Thakur S, Gupta N, Kakkar P. Serum copper and zinc concentrations and their relation to superoxide dismutase in severe malnutrition. Eur J Pediatr. 2004;163(12):742-44.

PARTICULARS OF CONTRIBUTORS:
1. Senior Resident, Department of Paediatrics, Institute of Child Health and Hospital for Children, Chennai, Tamil Nadu, India.
2. Assistant Professor, Department of Paediatrics, Institute of Child Health and Hospital for Children, Chennai, Tamil Nadu, India.
3. Assistant Professor, Department of Paediatrics, Institute of Child Health and Hospital for Children, Chennai, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Anusha Chelladurai,
Tamil Salai Road, Egmore, Chennai, Tamil Nadu, India.
E-mail: anudurai50@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 03, 2025
- Manual Googling: May 20, 2025
- iThenticate Software: Sep 10, 2025 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 10

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Mar 18, 2025**
Date of Peer Review: **Apr 16, 2025**
Date of Acceptance: **Sep 02, 2025**
Date of Publishing: **Sep 30, 2025**