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ORIGINAL ARTICLE

Serum Magnesium and Micronutrient Profiles in Severe Acute Malnutrition: A Cross-Sectional Study in a Tertiary Care Centre

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Abstract

Background: Severe acute malnutrition (SAM) is a major public health challenge associated with high morbidity and mortality. Micronutrient deficiencies, particularly magnesium, zinc, and copper, play a crucial role in clinical deterioration, yet their assessment is often overlooked in routine care. **Objectives:** To assess serum magnesium and other micronutrient profiles in children with SAM and evaluate their prevalence and distribution in relation to clinical and anthropometric characteristics. **Methodology:** A cross-sectional study was conducted among 70 children aged 6–59 months admitted with SAM to a tertiary care centre. Detailed clinical evaluation, anthropometric measurements, and laboratory investigations, including serum magnesium, zinc, and copper levels, were performed. Micronutrient deficiencies were classified based on established reference cut-offs. Data were analysed using SPSS 26.0. **Results:** The majority of children were aged 12–23 months (34.3%) and male (55.7%). Severe wasting was evident with a mean MUAC of 11.33 ± 0.50 cm. Mean serum magnesium was 1.78 ± 0.47 mg/dL, zinc 72.79 ± 31.18 µg/dL, and copper 99.99 ± 42.46 µg/dL. Magnesium deficiency (<1.6 mg/dL) was detected in 44.3% of children, zinc deficiency (<70 µg/dL) in 37.1%, and copper deficiency (<80 µg/dL) in 37.1%. Anaemia (mean haemoglobin 9.23 ± 1.99 g/dL) and low serum albumin (3.05 ± 0.59 g/dL) were also common. **Conclusion:** The present study concludes that children with SAM exhibit a high burden of micronutrient deficiencies, particularly magnesium, zinc, and copper, reflecting significant biochemical compromise. Routine screening and correction of these deficiencies should be prioritized to improve clinical outcomes in SAM.

Keywords: Severe acute malnutrition, Micronutrient deficiency, Serum magnesium

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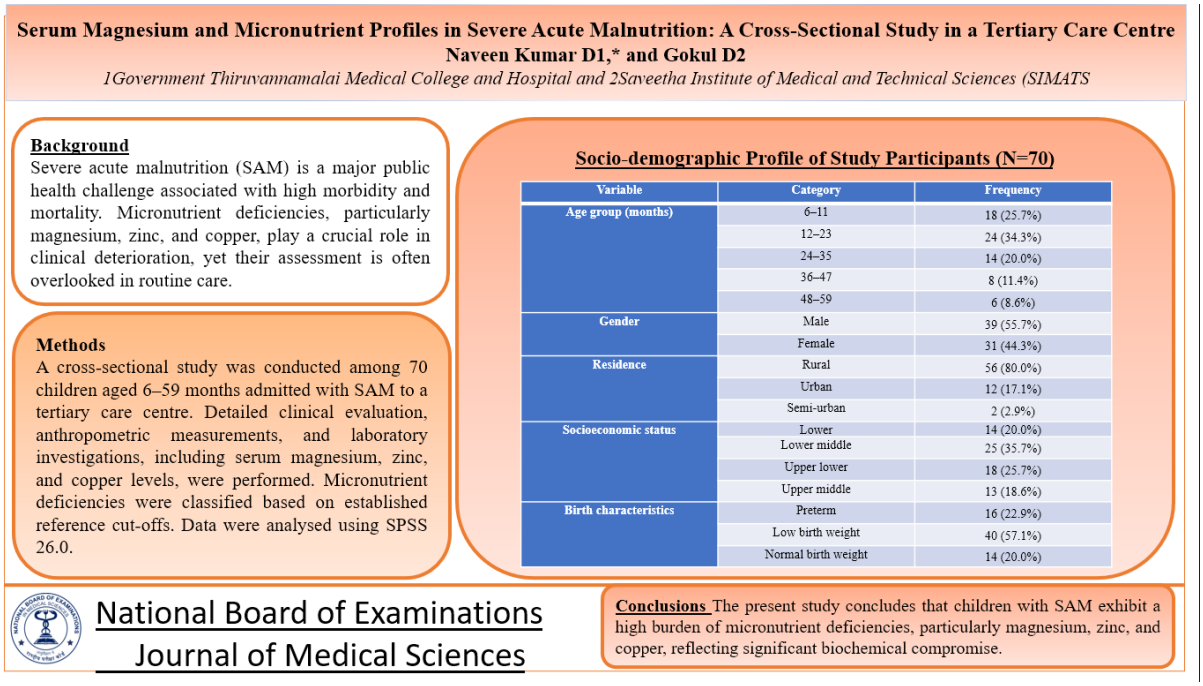
Graphical Abstract



Introduction

Severe acute malnutrition (SAM) remains one of the most critical public health challenges in developing countries, affecting approximately 16 million children under five years of age globally [1,2]. The condition is characterized by severe wasting, manifested by a weight-for-height z-score of less than -3 standard deviations or a mid-upper arm circumference of less than 115 mm, or by the presence of bilateral pitting oedema [1]. Despite significant advances in understanding the pathophysiology and management of SAM, mortality rates remain unacceptably high, ranging from 5% to 20% in hospital settings, with micronutrient deficiencies playing a substantial role in this elevated mortality [3,4].

Micronutrients, though required in minute quantities, are essential for numerous physiological processes, including immune function, growth, development, and cellular metabolism [5]. Children with SAM frequently exhibit multiple micronutrient deficiencies due to inadequate dietary intake, increased requirements during catch-up growth, impaired absorption secondary to enteropathy, and increased losses through diarrhoea and infections [6,7]. Among the various micronutrients, magnesium occupies a unique position as the second most abundant intracellular cation and serves as a cofactor for more than 300 enzymatic reactions [8]. Magnesium deficiency in SAM has been associated with increased risk of mortality, impaired recovery, cardiac arrhythmias, and neuromuscular dysfunction, yet it remains underrecognized and inadequately addressed in routine clinical practice [9,10].

The prevalence of hypomagnesemia in children with SAM varies widely across different studies, ranging from 20% to 80%, depending on the population studied and diagnostic criteria employed [9,11]. Similarly, deficiencies of other critical micronutrients including zinc, copper, selenium, and vitamins have been

documented with variable frequencies in malnourished children [6].

Current World Health Organisation (WHO) guidelines for the management of SAM include supplementation with a multi-micronutrient preparation, but these recommendations are based on limited evidence regarding the actual prevalence and severity of specific micronutrient deficiencies in different populations [1]. Furthermore, serum magnesium levels are not routinely measured in most resource-limited settings due to a lack of awareness, unavailability of laboratory facilities, and financial constraints [10]. This results in a significant gap between the actual micronutrient status of children with SAM and the standardized treatment protocols being implemented. The present study was therefore undertaken to assess serum magnesium levels and other micronutrient profiles in children with SAM admitted to a tertiary care center, and to correlate these findings with clinical characteristics and outcomes.

Methodology

Study Design and Setting

This cross-sectional observational study was conducted in the Pediatric Intensive Care Unit and Nutritional Rehabilitation Centre of a tertiary care teaching hospital in South India over a period of 18 months. The study was approved by the Institutional Ethics Committee and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from parents or legal guardians of all study participants after explaining the study objectives, procedures, and potential risks and benefits in their vernacular language.

Study Population

Children aged 6 months to 59 months admitted with a diagnosis of SAM according to WHO criteria were screened for eligibility

Sample Size Calculation

Based on a previous study by Singhal et al. [9] reporting hypomagnesemia prevalence of 35% in children with SAM, with an absolute precision of 11% and confidence level of 95%, the minimum required sample size was calculated to be 63 using the formula $n = Z^2pq/d^2$. Accounting for a potential 10% dropout rate, a total sample size of 70 children was planned for the study.

Inclusion Criteria

Children meeting the following criteria were included: age between 6 and 59 months; diagnosis of SAM as per WHO criteria; parents or guardians willing to provide informed consent; and children admitted within 24 hours of presentation to the hospital.

Exclusion Criteria

Those who received micronutrient supplementation within the previous 4 weeks, chronic kidney disease, congenital heart disease, or other chronic systemic illnesses, received diuretic therapy within the past 2 weeks, severe dehydration requiring immediate fluid resuscitation or parents or guardians unwilling to provide consent were excluded from the study

Clinical Assessment

A detailed clinical history was obtained including age, sex, duration of illness, feeding practices, immunization status, and associated symptoms. Sociodemographic information including

parental education, occupation, family income, and household food security status was recorded using a structured questionnaire. Thorough physical examination was performed documenting vital signs, anthropometric measurements, presence of edema, signs of micronutrient deficiencies (such as dermatosis, hair changes, angular stomatitis, pallor), and associated complications.

Anthropometric Measurements

Weight was measured using a calibrated electronic weighing scale (accuracy ±10 g) with children wearing minimal clothing. Recumbent length (for children <24 months) or standing height (for children ≥24 months) was measured using an infantometer or stadiometer (accuracy ±0.1 cm). MUAC was measured at the midpoint between the acromion and olecranon process of the left arm using a standard MUAC tape. All measurements were performed in duplicate by trained personnel and the average value was recorded.

Laboratory Investigations

Blood samples (5 mL) were collected within 24 hours of admission after antiseptic precautions under aseptic conditions. Samples were collected in trace element-free vacutainers after an overnight fast (or at least 4 hours of fasting in younger infants). Blood was allowed to clot at room temperature for 30 minutes and then centrifuged at 3000 rpm for 10 minutes. Serum was separated and stored in aliquots at -80°C until analysis. All samples were processed within 2 hours of collection [6]. Serum magnesium levels were measured using the xylidyl blue colorimetric method on an automated biochemistry analyser (Beckman Coulter AU680). Serum zinc levels were measured by atomic absorption spectrophotometry and serum copper and selenium levels were measured using inductively coupled plasma mass spectrometry

Data Analysis

Data were entered into Microsoft Excel 2019 and analysed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on distribution. Categorical variables were expressed as frequencies and percentages.

Results

Table 1. Socio-demographic Profile of Study Participants (N=70)

Variable	Category	Frequency
Age group (months)	6–11	18 (25.7%)
	12–23	24 (34.3%)
	24–35	14 (20.0%)
	36–47	8 (11.4%)

	48–59	6 (8.6%)
Gender	Male	39 (55.7%)
	Female	31 (44.3%)
Residence	Rural	56 (80.0%)
	Urban	12 (17.1%)
	Semi-urban	2 (2.9%)
Socioeconomic status	Lower	14 (20.0%)
	Lower middle	25 (35.7%)
	Upper lower	18 (25.7%)
	Upper middle	13 (18.6%)
Birth characteristics	Preterm	16 (22.9%)
	Low birth weight	40 (57.1%)
	Normal birth weight	14 (20.0%)

A total of 70 children were included in the study. The majority belonged to the 12–23-month age group (34.3%), followed by 6–11 months (25.7%). More than half of the children were males (55.7%). Most participants resided in rural areas (80%), and only 17.1% were from urban settings. Socioeconomic assessment revealed that 35.7% belonged to the lower-middle class and 25.7% to the upper-lower class. Regarding birth characteristics, 22.9% of the children were preterm, while low birth weight was observed in 57.1% of the study population. (Table 1)

Table 2. Anthropometric and Laboratory Parameters of the Study Population (N = 70)

Parameters	**Mean ± SD**	**Median**	**Min–Max**
Height (cm)	77.81 ± 11.34	75	49–102
Weight (kg)	7.09 ± 2.05	6.55	2.5–12
MUAC (cm)	11.33 ± 0.5	11.3	10.3–12.2
Haemoglobin (g/dL)	9.23 ± 1.99	9.7	4.9–12.9
Albumin (g/dL)	3.05 ± 0.59	3.1	1.4–4.2

The mean height and weight of the children were 77.81 ± 11.34 cm and 7.09 ± 2.05 kg, respectively. Mid-upper arm circumference (MUAC) showed severe wasting, with a mean of 11.33 ± 0.50 cm. The mean haemoglobin level was 9.23 ± 1.99 g/dL, indicating a high burden of anaemia. Serum albumin levels were also low, with a mean of 3.05 ± 0.59 g/dL, reflecting poor nutritional status. (Table 2)

Table 3. Serum Micronutrient Levels Among Children with SAM (N = 70)

Serum	**Mean ± SD**	**Median**	**Min**	**Max**	**95% CI**	
					Lower	**Upper**
Ferritin	34.25 ± 28.81	28.85	3.40	126.10	27.38	41.12
Zinc	72.79 ± 31.18	78.35	15.60	145.40	65.36	80.23
Magnesium	1.78 ± 0.47	1.70	1.10	2.90	1.67	1.89
Copper	99.99 ± 42.46	92.50	22.70	198.90	89.86	110.11

The mean ferritin level was 34.25 ± 28.81 ng/mL, while the mean serum zinc was 72.79 ± 31.18 µg/dL. Serum magnesium levels averaged 1.78 ± 0.47 mg/dL, and copper levels were 99.99 ± 42.46 µg/dL. Wide ranges were noted across all micronutrients, indicating heterogeneous biochemical profiles among children with SAM. (Table 3)

Table 4. Distribution of Serum Micronutrient Levels Among Children with SAM (N = 70)

Micronutrient	**Category**	**N (%)**
Serum Zinc (µg/dL)	< 70 (Low)	26 (37.1%)
	70–115 (Normal)	40 (57.1%)
	> 115 (High)	4 (5.7%)
Serum Magnesium (mg/dL)	< 1.6 (Low)	31 (44.3%)
	1.7–2.2 (Normal)	26 (37.1%)
	> 2.3 (High)	13 (18.6%)
Serum Copper (µg/dL)	< 80 (Low)	26 (37.1%)
	80–190 (Normal)	42 (60.0%)
	> 190 (High)	2 (2.9%)

Zinc deficiency (<70 µg/dL) was observed in 37.1% of children, while 57.1% had normal zinc levels. Magnesium deficiency (<1.6 mg/dL) was seen in 44.3% of participants, with 37.1% having normal values. Similarly, 37.1% of children had copper deficiency (<80 µg/dL), and 60% had normal copper levels. A smaller proportion showed elevated levels for all three micronutrients (Table 4).

Discussion

The present study revealed a high prevalence of micronutrient deficiencies among children with severe acute malnutrition, with hypomagnesemia observed in 44.3% of participants and zinc deficiency in 37.1%. These findings are consistent with previous reports highlighting the substantial burden of micronutrient deficiencies in this vulnerable population. Singhal et al. reported hypomagnesemia in 35% of children with SAM in their hospital-based study, which aligns closely with our observations [9]. The mean serum magnesium level in our study was 1.78 ± 0.47 mg/dL, comparable to the findings of Hother et al., who documented low serum magnesium concentrations in hospitalized Ugandan children with SAM and established a significant association between electrolyte abnormalities and mortality risk [10].

The prevalence of zinc deficiency observed in our cohort was similar to that reported by Srinivasan et al. in their cross-sectional study of severely malnourished children in rural Malawi, where multiple micronutrient deficiencies were documented alongside toxic element accumulation [6]. Their study emphasized the complex interplay between nutritional deficiencies and environmental exposures in contributing to the pathophysiology of SAM. The mean serum zinc level in our study (72.79 ± 31.18 µg/dL) was notably lower than reference values for healthy children, indicating substantial zinc depletion in this population. Our finding of copper deficiency in 37.1% of children, with a mean copper level of 99.99 ± 42.46 µg/dL, resonates with the observations of Bailey et al., who described the global epidemiology of micronutrient deficiencies and highlighted the widespread nature of these deficiencies in resource-limited settings [5].

The heterogeneous biochemical profiles noted in our study participants, with wide ranges across all measured micronutrients, reflect the variable nutritional insults and metabolic derangements characteristic of SAM. The mean haemoglobin level of 9.23 ± 1.99 g/dL in our cohort indicates a high burden of anaemia, which is frequently associated with multiple micronutrient deficiencies including iron, folate, and vitamin B12. Bhutta et al. in their comprehensive review on severe childhood malnutrition emphasized that micronutrient deficiencies contribute significantly to increased morbidity and mortality, supporting the need for routine screening and targeted supplementation strategies [3]. The low mean serum albumin level (3.05 ± 0.59 g/dL) observed in our study reflects the protein-energy malnutrition and hepatic dysfunction commonly seen in SAM, which can further impair micronutrient metabolism and utilization. The high proportion of children from rural areas (80%) and lower socioeconomic strata in our study, combined with the elevated prevalence of low birth weight (57.1%), underscores the multifactorial aetiology of SAM where poverty, food insecurity, and

adverse perinatal factors converge to create vulnerability to severe malnutrition and its associated complications. The mean MUAC of 11.33 ± 0.50 cm in our study population indicates severe wasting, consistent with WHO diagnostic criteria for SAM, and highlights the critical nutritional status of these children requiring urgent intervention [2].

Limitations

The single-centre study setting may limit the generalizability of findings to other geographic regions with different dietary patterns, disease burdens, and healthcare systems. Serum micronutrient levels may not accurately reflect total body stores or intracellular concentrations, particularly for magnesium, where less than 1% of total body content is present in serum. The study did not assess other important micronutrients such as vitamin A, vitamin D, folate, and vitamin B12, which are also commonly deficient in children with severe acute malnutrition. The lack of a control group of well-nourished children from the same geographic area limits the comparative interpretation of the findings. Finally, financial constraints prevented assessment of functional markers of micronutrient status such as enzyme activities or clinical response to supplementation, which would have provided a more comprehensive understanding of the clinical significance of the observed deficiencies.

Conclusion

The present study demonstrates a high prevalence of micronutrient deficiencies among children with severe acute malnutrition, with hypomagnesemia observed in 44.3% and zinc deficiency in 37.1% of participants. The mean serum magnesium level of 1.78 ± 0.47 mg/dL and mean serum zinc level of 72.79 ± 31.18 µg/dL indicate substantial depletion of these critical micronutrients in the study population. Additionally, copper deficiency was present in 37.1% of children, with a mean copper level of 99.99 ± 42.46 µg/dL. The severe wasting evidenced by mean MUAC of 11.33 ± 0.50 cm, coupled with low mean haemoglobin (9.23 ± 1.99 g/dL) and serum albumin levels (3.05 ± 0.59 g/dL), reflects the profound nutritional compromise in these children. These findings underscore the critical need for routine screening of serum magnesium and other essential micronutrients in this vulnerable population, as these deficiencies may contribute significantly to adverse outcomes and mortality. Future research should focus on longitudinal studies examining the impact of targeted micronutrient supplementation on clinical outcomes, recovery rates, and long-term neurodevelopmental consequences in children with SAM. Additionally, cost-effective strategies for routine micronutrient screening in resource-limited settings warrant further exploration to bridge the gap between current clinical practice and evidence-based management of severe acute malnutrition.

Ethical Approval

The study was approved by the Institutional Ethics Committee (IEC/2022/PED/045) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from parents or legal guardians of all study participants after explaining the study objectives, procedures, and potential risks and benefits in their vernacular language.

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Conflicts of interest

The authors declare that they do not have conflict of interest.

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