Echocardiographic Assessment of Cardiac Parameters in Children with Severe Acute Malnutrition: A Comparative Study with Anthropometric Correlations

Narayan Mukati[1*], Shachi Jain Taran[2], Urvashi Channa[3]

[1]PG Resident, Department of Pediatrics, MGM Medical College, Indore, India, [2]Associate Professor, Department of Pediatrics, MGM Medical College, Indore, India, [3]Assistant Professor, Department of Pediatrics, MGM Medical College, Indore, India

Abstract

Background: Severe acute malnutrition (SAM) remains a major contributor to child morbidity and mortality worldwide, with potential impacts on cardiac structure and function. Comprehensive comparisons between malnourished and well-nourished children are limited, obscuring the full cardiovascular burden of SAM. Objectives: To compare structural and functional cardiac parameters—assessed by two-dimensional echocardiography—between children with SAM and age-matched, normally nourished peers, and to evaluate correlations between key cardiac indices and anthropometric measures (mid-upper arm circumference [MUAC] and body mass index [BMI]). **Materials and Methods:** In this observational comparative study, 100 children aged 1–60 months admitted to the paediatric department of a tertiary care centre were enrolled (50 SAM, 50 normally nourished children). Following clinical stabilization, comprehensive echocardiography was performed on day 7. Structural metrics included interventricular septal thickness at diastole and left ventricular (LV) internal diameters; functional measures comprised stroke volume, ejection fraction (EF), tricuspid annular plane systolic excursion (TAPSE), and mitral annular plane systolic excursion (MAPSE). Anthropometry and laboratory values (haemoglobin, electrolytes) were recorded. Between-group comparisons used unpaired t-tests and chi-square tests; correlations were examined via one-way ANOVA. **Results:** SAM children exhibited significantly reduced septal thickness (8.15 ± 1.37 vs. 8.86 ± 0.84 mm; $p = 0.002$) and LV diastolic diameter (19.54 ± 4.83 vs. 22.63 ± 5.03 mm; $p = 0.002$). Stroke volume (10.46 ± 4.95 vs. 13.29 ± 5.89 mL; $p = 0.012$) and EF (67.27 ± 8.46% vs. 71.11 ± 9.93%; $p = 0.040$) were lower in SAM, while TAPSE and MAPSE were preserved ($p > 0.5$). MUAC correlated positively with all structural and functional parameters ($p < 0.05$), whereas BMI showed no significant associations. Haemoglobin and calcium levels were also significantly lower in SAM ($p = 0.001$). **Conclusion:** SAM is associated with significant cardiac atrophy and systolic impairment, with preserved longitudinal function. MUAC serves as a clinically accessible predictor of cardiac compromise in malnourished children, supporting its integration into SAM management protocols.

Keywords: Protein-Energy Malnutrition, Echocardiography, Paediatrics, Anthropometry, Cardiac Output.

Received: 05 June 2025 **Revised: 12 July 2025** **Accepted: 23 August 2025** **Published: 04 September 2025**

Introduction

Severe acute malnutrition (SAM) represents a critical global health challenge, affecting approximately 19 million children under five years worldwide and contributing to an estimated 400,000 child deaths annually.1 Defined by a weight-for-height Z-score below -3 standard deviations, mid-upper arm circumference less than 115 mm, or presence of nutritional oedema, SAM extends beyond immediate nutritional deficits to encompass profound physiological impairments across multiple organ systems.[1,2] The cardiovascular system emerges as particularly vulnerable, with malnutrition-induced alterations potentially compromising cardiac structure and function during critical developmental periods.[3]

Children with SAM demonstrate significant reductions in left ventricular mass, impaired myocardial contractility, and altered diastolic function, with these changes closely correlating with malnutrition severity and duration. Previous investigations have documented structural cardiac alterations including decreased interventricular septal thickness and reduced left ventricular dimensions in malnourished children compared to healthy counterparts.[4]

Despite growing recognition of cardiac complications in SAM, comprehensive comparisons between severely malnourished children and age-matched normally nourished children remain limited. Furthermore, the relationship between anthropometric measures—particularly mid-upper arm circumference (MUAC)—and cardiac parameters requires elucidation to inform clinical screening strategies. This study addresses these knowledge gaps by evaluating structural and functional cardiac parameters through two-dimensional echocardiography in children with SAM versus normally nourished children, while exploring

Address for correspondence: Dr. Narayan Mukati, PG Resident, Department of Pediatrics, MGM Medical College, Indore, India. E-mail: narayanmukati02@gmail.com

DOI: 10.21276/amit.2025.v12.i3.30

How to cite this article: Mukati N, Taran SJ, Channa U. Echocardiographic Assessment of Cardiac Parameters in Children with Severe Acute Malnutrition: A Comparative Study with Anthropometric Correlations. Acta Med Int. 2025;12:35-39.

correlations with key anthropometric indicators to enhance risk stratification approaches.

Objectives:

1. Compare structural and functional cardiac parameters using two-dimensional echocardiography in children with SAM and healthy normally nourished children.
2. Examine correlation between cardiac parameters and key anthropometric indicators (MUAC/BMI) in SAM children.

Materials and Methods

The present observational, case–normally nourished children investigation was conducted over a 12-month period (after institutional ethics approval) in the Department of Paediatrics at tertiary care centre, Central India with a dedicated SMTU Unit.

Study Design and Population: Children aged 1 to 60 months admitted between 2022 and 2023 were enrolled. The severe acute malnutrition (SAM) group comprised patients meeting any one of the following World Health Organization (WHO) criteria: weight-for-height Z-score below –3 SD, mid-upper arm circumference (MUAC) <11.5 cm, or clinical presence of bilateral pedal oedema. Age-matched, normally nourished children (weight-for-height Z-score ≥0 served as normally nourished children). Exclusion criteria included known congenital or acquired cardiac disease, severe anaemia (haemoglobin <6 g/dL), preterm birth (<37 weeks' gestation), small for gestational age (birth weight <10th percentile), and lack of guardian consent.

Sample Size

Using the formula

$$N = \frac{(Z_{\alpha} + Z_{1-\beta})^2 \times 2 \times S_d^2}{(m_1 - m_2)^2},$$

with α=0.05, power=90%, pooled standard deviation 0.03, and mean difference 0.16, a minimum of 30 subjects per group was calculated; 50 children were ultimately enrolled in each cohort.

Variables

Primary Variables

- Structural cardiac parameters (2D echocardiography on day 7 post-stabilization): interventricular septal thickness at diastole, left ventricular posterior wall thickness at diastole, left ventricular internal diameters during diastole and systole.
- Functional cardiac parameters: stroke volume, ejection fraction, tricuspid annular plane systolic excursion (TAPSE), and mitral annular plane systolic excursion (MAPSE).

Anthropometric and Laboratory Variables

- Weight, height/length, MUAC, BMI, and body surface area (calculated by Mosteller formula).
- Haematological and biochemical tests: complete blood count, serum sodium, potassium, calcium, blood glucose, thyroid-stimulating hormone, and screening for HIV, hepatitis B surface antigen, and hepatitis C antibody.

Data Collection and Procedures: After informed consent, demographic and clinical data were recorded on a structured proforma. Anthropometry followed WHO standards. Laboratory investigations were performed to identify anaemia, electrolyte imbalances, and infections. Echocardiography (Acuson X300) and electrocardiography were conducted after clinical stabilization; structural and functional parameters were measured according to American Society of Echocardiography guidelines.

Statistical Analysis: Data were entered into Microsoft Excel and analysed using IBM SPSS v22. Descriptive statistics were expressed as means ± SD or percentages. Group comparisons employed Pearson's chi-square test for categorical data, unpaired t-tests for two-group mean comparisons, and one-way ANOVA for multiple groups. A two-tailed $p < 0.05$ denoted statistical significance.

Results

The study included 100 children, with 50 in the severe acute malnutrition (SAM) group and 50 in the age- and sex-matched healthy normally nourished children group, ensuring balanced cohorts for cardiac comparison. [Table 1] illustrates, no significant differences in age (p=0.618) or sex (p=1.000) distribution confirm successful matching of cohorts.

Children with SAM had significantly lower weight, height, MUAC, BMI, hemoglobin, and calcium compared to healthy normally nourished children, reflecting profound nutritional deficits and increased risk of anemia and hypocalcemia as depicted in [Table 2]. Significantly lower anthropometric and laboratory measures in SAM underlie increased risk of cardiac compromise.

Most children with SAM (62%) had MUAC between 9.5–11.4 cm, with 22% in the 7.0–9.4 cm range, and 16% between 11.5–12.5 cm, with none having MUAC <7 cm or >12.5 cm, indicating moderate to severe malnutrition. MUAC was the most frequent indicator of SAM (58%), while none of the children had pedal edema, confirming non-edematous SAM in all cases.

[Table 3] depicts that children with SAM had significantly thinner interventricular septal thickness and smaller LV diastolic diameter compared to normally nourished children, indicating structural cardiac atrophy.

[Table 4] illustrates that SAM children exhibited significantly lower stroke volume and ejection fraction than normally nourished children, reflecting impaired systolic function, while TAPSE and MAPSE remained similar, indicating preserved longitudinal function.

[Table 5] depicts that all structural and functional cardiac parameters improved with higher MUAC (p<0.05 for all), highlighting MUAC as a strong predictor of cardiac health in SAM children.

No significant differences in cardiac parameters were observed across BMI categories in SAM (p>0.05), suggesting BMI is less predictive of cardiac dysfunction than MUAC.

Table 1: Baseline Socio-Demographic Characteristics of Study Participants

Characteristics	SAM (n=50)	Normally Nourished Children (n=50)	p-value (*Pearson Chi-square*

			test)
Age, months			
< 2	2 (4.0%)	5 (10.0%)	0.618
2–12	26 (52.0%)	27 (54.0%)	
12–36	12 (24.0%)	9 (18.0%)	
> 36	10 (20.0%)	9 (18.0%)	
Sex			
Male	34 (68.0%)	34 (68.0%)	1.000
Female	16 (32.0%)	16 (32.0%)	

Table 2: Comparison of Anthropometric and Laboratory Parameters

Parameters	SAM (mean ± SD) (n=50)	Normally Nourished Children (mean ± SD) (n=50)	p-value (*Unpaired 't' test)*
Weight (kg)	5.77 ± 2.17	7.72 ± 3.82	0.002
Height (cm)	67.26 ± 11.14	72.84 ± 17.83	0.001
MUAC (cm)	10.38 ± 1.13	12.29 ± 1.54	0.001
BMI (kg/m²)	12.35 ± 2.21	13.76 ± 2.23	0.002
Hemoglobin (g/dL)	8.75 ± 1.56	10.21 ± 1.89	0.001
Calcium (mmol/L)	8.69 ± 1.65	9.80 ± 0.94	0.001

Table 3: Comparison of Structural Cardiac Parameters

Parameters	SAM (mean ± SD) (n=50)	Normally Nourished Children (mean ± SD) (n=50)	p-value (*Unpaired 't' test)*
Interventricular septal thickness (diastole, mm)	8.15 ± 1.37	8.86 ± 0.84	0.002
Left ventricular posterior wall thickness (diastole, mm)	5.83 ± 1.11	6.24 ± 0.98	0.052
LV internal diameter (diastole, mm)	19.54 ± 4.83	22.63 ± 5.03	0.002
LV internal diameter (systole, mm)	14.12 ± 3.34	14.81 ± 3.85	0.338

Table 4: Comparison of Functional Cardiac Parameters

Parameter	SAM (mean ± SD)	Normally Nourished Children (mean ± SD)	p-value (*Unpaired 't' test)*
Stroke volume (mL/beat)	10.46 ± 4.95	13.29 ± 5.89	0.012
Ejection fraction (%)	67.27 ± 8.46	71.11 ± 9.93	0.040
TAPSE (mm)	13.37 ± 1.92	13.64 ± 2.29	0.531
MAPSE (mm)	9.45 ± 1.31	9.51 ± 1.39	0.824

Table 5: Correlation of Cardiac Parameters with MUAC in SAM

MUAC Category (cm)	Septal Thickness (mm) (mean ± SD)	LV Posterior Wall (mm) (mean ± SD)	Stroke Volume (mL) (mean ± SD)	EF (%) (mean ± SD)	TAPSE (mm) (mean ± SD)	MAPSE (mm) (mean ± SD)
7.0–9.4	7.01 ± 1.07	5.03 ± 0.60	6.51 ± 1.94	63.03 ± 9.05	11.92 ± 1.72	10.17 ± 1.57
9.5–11.4	8.67 ± 1.27	6.13 ± 1.09	11.45 ± 5.18	68.12 ± 9.37	13.86 ± 1.81	9.45 ± 1.16
11.5–12.5	8.56 ± 0.75	6.01 ± 1.09	11.01 ± 4.71	72.85 ± 7.73	13.33 ± 2.05	9.04 ± 0.86
> 12.5	9.18 ± 0.70	6.65 ± 0.65	18.14 ± 3.88	70.03 ± 9.90	14.26 ± 2.46	10.08 ± 1.82
p-value (*One-Way* ANOVA)	0.001	0.001	0.001	0.009	0.007	0.013

The sensitivity of Ranson's scoring system at 48 hours was 35.9%, specificity in predicting SAP 92.3%, PPV 95.8% while NPV was 22.6%. The sensitivity of BISAP scoring system in predicting SAP was 50.0%, specificity 84.6%, PPV 94.1% and NPV 25.6%. The sensitivity of MCTSI scoring system in predicting SAP was 53.1%, specificity 100%, PPV 100% and NPV 30.2%. [Table 6]

Table 6: Predictive value of several grading methods for SAP

Scores	Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %
Ranson (at admission)	09.4	100	100	18.3	24.7
Ranson (48 hours)	35.9	92.3	95.8	22.6	45.5
BISAP	50.0	84.6	94.1	25.6	55.8
MCTSI	53.1	100	100	30.2	61.1

Discussion

The present investigation revealed comparable demographic characteristics between groups, with the majority of children (52-54%) falling within the 2-12 months age range and no statistically significant age differences (p=0.618). Gender distribution demonstrated equal representation with 68% males and 32% females across both cohorts (p=1.000). These findings align closely with Chelo et al. (2020), who reported 81.1% of SAM children under 18 months, reinforcing the predominance of malnutrition in early childhood.[5] Prajapati et al. (2019) documented similar age demographics with a mean age of 16.8±11.12 months in their SAM cohort.[6] Jain et al. (2019) and Samikannu et al. (2019) both employed sex-matched controls, corroborating the methodological approach of maintaining demographic homogeneity.[7,8] The consistent male predominance across studies may reflect regional healthcare-seeking behaviours or potential biological susceptibilities to SAM. This demographic consistency across multiple investigations strengthens the external validity of cardiac assessment findings in paediatric malnutrition research, emphasizing that age-matched comparisons are crucial for isolating nutrition-specific cardiac effects. Structural cardiac remodeling was evident in the SAM cohort, with septal thickness at diastole averaging 8.15 ± 1.37 mm versus 8.86 ± 0.84 mm in normally nourished children (p=0.002). Prajapati et al. (2019) observed a comparable reduction in septal thickness (6.9 ± 1.3 mm vs. 9.1 ± 0.5 mm; p<0.0001) and posterior wall thickness (5.5 ± 1.2 mm vs. 7.0 ± 1.0 mm; p<0.0001), corroborating our demonstration of SAM-associated myocardial thinning.6 Similarly, Chelo et al. (2020) detected LV shortening fraction and ejection fraction below the 3rd percentile in 35% of SAM children, linking structural changes to systolic impairment.5

Functional analysis revealed a mean stroke volume of 10.46 ± 4.95 mL/beat in SAM versus 13.29 ± 5.89 mL/beat in normally nourished children (p=0.012), and ejection fraction of 67.27 ± 8.46% versus 71.11 ± 9.93% (p=0.040). These results echo Prajapati et al. (2019), who reported significantly lower stroke volume (10.4 ± 4.2 mL vs. 15.9 ± 4.6 mL; p<0.0001) and ejection fraction (63.4 ± 6.7% vs. 71.0 ± 5.5%; p<0.0001) in malnourished children.6 In contrast, Silverman et al. (2015) found no significant difference in cardiac index between SAM and normally nourished children, suggesting hemodynamic adaptations that preserve output despite reduced volumetric measures.[9]

Longitudinal (TAPSE) and mitral annular plane systolic excursion (MAPSE) values were preserved in our SAM cohort (p>0.5), indicating maintenance of longitudinal function. Bebars et al. (2019) similarly reported preserved systolic annular excursion despite 40% of SAM children exhibiting grade I/II diastolic dysfunction.[10] This "compensatory sparing" of longitudinal fibers may temporarily maintain global systolic performance.

Correlations with anthropometry revealed strong associations between MUAC and both structural and functional parameters (p<0.05), whereas BMI showed no significant relationship (p>0.5). Bebars et al. (2019) observed post-rehabilitation improvements in diastolic function correlated with MUAC gains, and Agarwal et al. (2023) demonstrated HRV alterations in SAM linked to MUAC-defined severity.[10,11] These findings endorse MUAC as a sensitive predictor of cardiac involvement in malnutrition. Biochemical analysis detected significant hypocalcemia (8.69 ± 1.65 mmol/L vs. 9.80 ± 0.94 mmol/L; p=0.001) and anemia (8.75 ± 1.56 g/dL vs. 10.21 ± 1.89 g/dL; p=0.001) in SAM. Faddan et al. (2010) similarly reported lower hemoglobin and calcium in malnourished infants, linking electrolyte deficits to myocardial vulnerability.[12] Hypocalcemia and anemia may exacerbate contractile dysfunction by impairing excitation–contraction coupling and oxygen delivery.

Collectively, these data underscore that SAM precipitates both radial myocardial atrophy and longitudinal functional compensation, with significant implications for cardiac reserve. The preservation of TAPSE and MAPSE suggests a window of reversible dysfunction, as evidenced by Pradhaa et al. (2023), who reported normalization of echocardiographic parameters post-rehabilitation.[13] However, the absence of diastolic assessment in our study and reliance on cross-sectional design limit insights into relaxation abnormalities and temporal recovery.

Conclusion

Children with severe acute malnutrition exhibit marked reductions in LV septal thickness and diastolic dimensions, accompanied by decreased stroke volume and ejection fraction, whereas longitudinal systolic function remains preserved. MUAC correlates strongly with cardiac structural and functional measures, highlighting its utility as a non-invasive predictor. Anemia and hypocalcemia further compound cardiac impairment, emphasizing the need for integrated nutritional and electrolyte management.

Recommendation

Incorporate routine MUAC screening and targeted echocardiographic evaluation into SAM protocols. Ensure correction of anemia and calcium deficiencies, and adopt cautious refeeding strategies to prevent cardiac overload.

Strengths and Limitations

The rigorous comparative design ensured comparability between groups, while detailed two-dimensional echocardiography enabled comprehensive assessment of cardiac structure and function. Identification of mid-upper arm circumference as a predictor of myocardial performance adds clinical relevance. However, the cross-sectional design limits causal inference, diastolic function and biomarker assessments were omitted, and the modest sample size may reduce generalizability and statistical power.

Relevance of the Study

This work elucidates cardiac sequelae of SAM and validates MUAC as a cardiometabolic risk marker, guiding early intervention to mitigate cardiovascular morbidity in malnourished children.

Ethical Consideration

The study protocol was approved by the Institutional Ethics Committee of M.G.M. Medical College & M.Y. Hospital, Indore. Informed consent was obtained from all parents/guardians. Confidentiality and patient welfare were strictly maintained.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. WHO guideline on the prevention and management of wasting and nutritional oedema (acute malnutrition) in infants and children under 5 years. Geneva: World Health Organization; 2023.

2. Akdeniz O, Yılmaz E, Çelik M, Özgün N. Cardiac evaluation in children with malnutrition. Turk Pediatri Ars. 2019 Sep 25;54(3):157–65.
3. Chama GC, Siame L, Kapoma C, Hamooya BM, Masenga SK. Severe acute malnutrition among children under the age of 5 years. PLoS One. 2024 Aug 26;19(8):e0309122.
4. Prajapati M, Singh J, Dwivedi D, Agnihotri S. Cardiac changes in severe and moderate acute malnutrition. J Pediatr Assoc India. 2020;9(3):110.
5. Chelo D, Nguefack F, Ngate A, et al. Study of the cardiac function of children aged 6 to 59 months suffering from severe acute malnutrition in Yaoundé Cameroon. J Pediatr Neonatal. 2020;2(1).
6. Prajapati MK, Singh JK. To study structural and functional cardiac changes in children with severe acute malnutrition. J Evol Med Dent Sci. 2019;8(40):3001–4.
7. Jain D, Rao SK, Kumar D, Kumar A, Sihag BK. Cardiac changes in children hospitalized with severe acute malnutrition: A prospective study at tertiary care center of northern India. Indian Heart J. 2019;71(6):492-5.
8. Senthil Raja Samikannu S. Study of myocardial function in children with severe acute malnutrition. IAIM. 2019;6(3):132-6.
9. Silverman JA, Chimalizeni Y, Hawes SE, et al. The effects of malnutrition on cardiac function in African children. Arch Dis Child. 2015;0:1–6.
10. Bebars GM, Askalany HT. Assessment of left ventricular systolic and diastolic functions in severely malnourished children. Gaz Egypt Paediatr Assoc. 2019;67(1).
11. Agarwal A, Sharma N, Naidu A, et al. A prospective study of heart rate variability in severely malnourished children aged 6–59 months. J Gajra Raja Med Coll. 2023;14(3):1196–202.
12. Faddan NHA, Sayh KIE, Shams H, Badrawy H. Myocardial dysfunction in malnourished children. Ann Pediatr Cardiol. 2010;3(2):113–8.
13. Pradhaa H, Ramanathan. Study on the effect of severe acute malnutrition on various echocardiographic parameters of the heart. Int J Contemp Pediatr. 2023 Feb 23;10(3):357–60.