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Original article

Biochemical and anthropometric correlates of bio-electrical impedance parameters in severely malnourished children: A cross-sectional study

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SUMMARY

Introduction: Despite expanding use of bio-impedance (BI), little is known about its pathophysiologic significance and biological correlates

Objective: Determine correlations of BI parameters with anthropometry and biomarkers of electrolyte homeostasis, inflammation and liver function in children with severe acute malnutrition (SAM).

Methods: We studied Ethiopian children with SAM (mid-arm circumference <11·0 cm or weight-for-height <70% of the NCHS growth reference median and/or nutritional oedema) at hospitalization. Impedance (Z, Ohm), resistance (R, Ohm), reactance (Xc, Ohm) and phase angle (PA, degree) were measured at 50 kHz. R and Xc were height-indexed. Anthropometric Z-scores were calculated. Serum phosphate, Ca, Na, K, Mg, alkaline phosphatase, bilirubin, α1-acid glycoprotein, albumin and haemoglobin were measured. Healthy children were used for BI comparison. Correlates of BI were established using forward selection after comparing models using likelihood ratio test.

Results: The sample comprised 55 children with SAM (age 36 ± 24 months; 60% males; 72.7% oedematous) and 80 healthy control children (age 28 ± 15 months; 47.5% males). Oedematous children had the lowest BI parameters compared with reference and non-oedematous children. Similarly, they had lower serum albumin, K and alkaline phosphatase levels than non-oedematous children. Oedema was independent negative correlate of R, Xc and PA. Serum albumin level and weight-for-height Z-score were positive correlates of R, whereas serum calcium and Cl levels were positive correlates of Xc. MUAC correlated positively with PA.

Conclusion: Nutritional oedema explained the divergence of BI parameters from normality. Soft tissue mass, serum albumin, Ca and Cl accounted for variability of BI parameters in children with SAM.

1. Introduction

Bio-electrical impedance (BI) techniques are non-invasive, safe and easy to use compared with other methods for body composition (BC) assessment [1]. The conventional approach assumes that height-adjusted impedance is proportional to total body water, which can be used to calculate lean and fat mass. However, the clinical validity of this approach is compromised in individuals characterised by abnormal fluid status and/or body disproportion. For instance, in children with severe acute malnutrition (SAM), oedema greatly reduces the accuracy of BI estimates [2]. To circumvent the challenges in sick individuals, the use of raw BI values alone or in combination (vector analysis or BIVA), has been suggested [3].

In adult patients with chronic cardiac failure phase angle (PA) was associated with lower haemoglobin, poor cardiac function and renal failure; more importantly, those with PA < 4.4 were at higher risk of death [4]. Values of reactance (Xc) and PA are presumed to indicate “cellular health” [5], which in itself is poorly defined.

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List of abbreviations

BI	Bio-electrical impedance
BIVA	Bio-electrical impedance vector analysis
BC	Body composition
PA	Phase angle
Xc	Reactance
R	Resistance
SAM	Severe acute malnutrition

Similarly, patients with oedema show increments in resistance (R) in association with loss of oedema [6]. Based on a review of the literature regarding the clinical relevance and applicability of raw BI values, PA was identified as a prognostic marker while BIVA has been recommended as a screening tool to identify patients with impaired functional status [7].

The clinical usefulness of the innovate approaches that can potentially replace the assumption-dependent and error-prone equations is well documented, though data is still scarce in clinical nutrition in childhood [8]. However, evidence is lacking regarding the biological correlates of BI parameters in sick individuals. Consequently, it is difficult to interpret cross-sectional or serial BI data, and this hinders utilization of the innovative methods. In this study, we examined the relationship between BI parameters and markers of electrolyte homeostasis, liver function and inflammation, and anthropometry in children hospitalized with SAM. These parameters are commonly used, combined with clinical examination, to assess disease progress, treatment outcome or identify patients at high risk of death early.

2. Methods

2.1. Study setting and subjects

The study was conducted in the Nutrition Rehabilitation Unit (NRU) of Jimma University Specialized Hospital, Ethiopia, from November 2010 to September 2011. The authors have previously published data from this site [2]. Eligible children were those 6–60 months old admitted with SAM, defined as MUAC <11·0 cm or weight-for-height (WFH) < 70% of NCHS growth reference median and/or nutritional oedema. Children with life-threatening illness like shock or sever respiratory distress or who were readmitted with SAM were excluded.

2.2. Data collection

Children were weighed with minimal clothing to the nearest 10 g using a pediatric scale (Tanita BD 815 MA, Tokyo, Japan). For children less than 2 years or those not able to stand, length was measured to the nearest 0·1 cm using a length board (SECA 416, Hamburg, Germany). In children older than 2 years of age, 0·5 cm was subtracted if they were not able to stand. In older children, height was measured to the nearest 0·1 cm using a free-standing stadiometer (SECA 214, Hamburg, Germany). MUAC was measured to the nearest 0·1 cm using a strip (SECA 2012, Hamburg, Germany). Pitting oedema was checked by gentle pressure with the thumb on the feet for 3–5 s.

BI parameters i.e. impedance in Ohm, R in Ohm, Xc in Ohm and PAin degrees were measured at 50 kHz using a Quadscan 4000 analyser (Bodystat, UK) as described previously [9]. It emitted 200 Micro Amps root mean square of alternating current. In brief, self-adhesive disposable electrodes were attached at the right hand and foot, injecting leads were connected to the electrodes just behind the finger and toe and the measuring leads were then connected to the electrodes on the right wrist and right ankle. Measurements were taken in triplicate 5 min apart, with children supine and limbs abducted.

Healthy children of 6–60 months old (WFH and height-for-age within ± 2SD of WHO growth standard) were recruited among vaccination attendees and children in day-care centre. The BI parameters in this group were measured with both equipment and protocol as for the SAM children. Two research nurses collected the data.

In the patients, venous blood was collected into dry tube and EDTA tube for separation of serum and haemoglobin determination, respectively. Serum was separated within an hour and kept at −80 °C for later blood chemistry analysis. Serum phosphate (P), Ca, Mg, Na, K and Cl were measured (Abbott Diagnostics, ref no 2P32-11 and 2P32-50) at International Clinical Laboratory (ISO 15189, Testing Laboratory No. M0221). Architect C4000 system (Abbott Diagnostics, USA) was used to measure P (Abbott Diagnostics, ref no 7D71-20&7D70-30), Mg (Randox Laboratories, UK, ref no MG531), Ca (Abbott Diagnostics, Ref no 3L79-31), albumin (Abbott Diagnostics, ref no 7D53-20) and bilirubin (Abbott Diagnostics, ref no 6L45-20 and 6L45-40) in serum. An automated Humastar 80 analyser (Human Diagnostics, Wiesbaden, Germany) was used to measure α_1-acid glucoprotein (AGP) (code Q0326, DAKO Denmark A/S, Glostrup, Denmark) and alkaline phosphatase (Human diagnostics ref no 12117) in serum. Haemoglobin was measured from whole blood samples collected in EDTA tubes using HemoCue® (Hb 201+, Ängelholm, Sweden).

Reference ranges for the age group of children in the study provided by the laboratories were: P (1.1–2.0 mmol/L), Ca (2.2–2.7 mmol/L), Mg (0.70–0.95 mmol/L), albumin (38–54 g/L), Na (138–145 mmol/L), K (3.4–4.7 mmol/L), Cl (98–113 mmol/L) and alkaline phosphatase (<400 U/L). The reference value for AGP (0.5–1.2 g/L) was not age-specific.

Written informed consent was obtained from caretakers or parents. Research Ethical Review Committee of Jimma University approved the study. All measurements were done after commencement of standard management and within 24 h of admission.

2.3. Statistics and data handling

Data were double-entered into EpiData version 3·1 (EpiData Association, Odense, Denmark) and analyzed with Stata/IC 12·1 (StataCorp, Texas, USA). WHO growth standard based anthropometric z-scores were calculated using Stata. R and Xc were indexed to height by division (R/H and Xc/H respectively). Continuous data were presented as mean ± standard deviation; categorical data were presented as n (%). Two-sample t-tests and chi-square test were used to compare SAM and healthy children. Correlation between continuous independent and dependent variables was assessed using Pearson's correlation coefficient.

The dependent variables were R/H and Xc/H, and unadjusted PA. Results of Z and R were similar and hence only results for R were shown. The following covariates were included in the final model: anthropometric indices, age, sex, MUAC, and serum AGP, Na, K, P, Ca, Mg, Cl, bilirubin, albumin, alkaline phosphatase and haemoglobin. To test if the relationship of serum albumin and BI varies with oedema, 2-way interaction term (albumin## oedema) was included in the model. Variance inflation factors to check for multicollinearity between independent variables. Final models were established using forward selection after comparing models by likelihood ratio test.

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