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Briefing papier 2018

# MOVING BEYOND ANTHROPOMETRY:

## CONDUCTING BIO-ELECTRICAL IMPEDANCE ANALYSIS (B.I.A) TO MEASURE BODY COMPOSITION IN ACUTELY MALNOURISHED CHILDREN:

Lessons from operational research


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# ACKNOWLEDGEMENTS

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## AUTHORSHIP

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[1] Modelling an Alternative Nutrition protocol Generalizable to Outpatient care - Burkina Faso
[2] Optimized Diagnosis and Monitoring of SAM – Burkina-Faso, Liberia & Bangladesh

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# GLOSSARY

| | | |
|---|---|---|
| **AAH** | **Action Against Hunger** | A non-governmental organisation |
| **BIA** | **Bio-electrical Impedance Analysis** | Method for measuring the electrical properties of organic bodies.<br>It can be used to evaluate fat-free mass and total body water, and indirectly fat mass. |
| **BIVA** | **Bio-electrical Impedance Vector Analysis** | Mathematical method to analyse BIA data. It is employed to assess fat-free mass & hydration status using raw BIA parameters standardized for height and plotted as point vectors on an " R-Xc graph ". |
| **BMI** | **Body Mass Index** | Index used to assess nutritional status - Defined by weight in kg divided by height squared in meters. |
| **FFM** | **Fat-Free Mass** | All components of body weight except body fat. Note that adipose tissue does also contain water hence body components are not strictly delimitated. |
| **FM** | **Fat Mass** | Fat Mass, does not contain water |
| **HAZ** | **Height-for-age z-score** | Index for comparing a child's height at a given age to a reference population and to identify stunting when HAZ < -2 z-score. |
| **LNS** | **Lipid based Nutrient Supplement** | Nutritional supplements providing lipids and micronutrients, often used in humanitarian action. |
| **MAM** | **Moderate Acute Malnutrition** | Loss of weight defined by a child presenting -3 ≤ WHZ <-2 and/or 115mm ≤ MUAC <125mm. |
| **MUAC** | **Mid Upper Arm Circumference** | Measurement of the left arm that indicates a loss of weight/wasting if < 125 mm among children under 5. |
| **PHASE ANGLE** | **Phase Angle** | Linear method of measuring the relationship between R and Xc vectors. It reflects the electrical properties of tissues, and it is affected by disease, nutritional and hydration status. |
| **R** | **Resistance** | Opposition to the flow of an electrical current generated by extra and intracellular fluids, inversely related to body water and electrolyte content of tissues. |
| **RUTF** | **Ready to Use Therapeutic Food** | Nutritional treatment for Severe Acute Malnourished children, a packaged food ready to use that does not need cooking. Nutritional value & composition are framed by UN statement in 2007.<br>http://www.who.int/maternal_child_adolescent/documents/a91065/en/. |

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|---|---|---|
| **SAM** | **Severe Acute Malnutrition** | Severe loss of weight defined by WHZ < -3 and/or MUAC < 115 mm and/or bilateral pitting edemas (independent of weight loss). |
| **TBW** | **Total Body Water** | Largest component of body weight, comprising Intracellular Water & Extracellular Water. |
| **WHZ** | **Weight-for-height z-score** | Index for comparing a child's weight for a given height to a reference population and to identify wasting when WHZ < -2 z-score. |
| **XC** | **Reactance** | Capacitance properties of cell membranes. It reflects the body cell mass, but also its integrity and composition. |
| **Z** | **Impedance** | It is a measure of the relationship between R and Xc of the body. It is measured in Ohms. |

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# WHO IS THIS DOCUMENT INTENDED FOR?

This document is intended for the international nutrition & health community from civil society representatives, health authorities, health personnel, NGO staff, policy makers, governments, donors, to scientific entities.

# WHAT IS THE OBJECTIVE OF THE DOCUMENT?

Its aim is to describe the principles of Bioeletrical Impedance analysis (BIA), and to propose practical steps in collecting good quality BIA data, based on our experience in a clear and concise form. We wish to help stakeholders understand how to implement BIA measurements in an operational research setting in the field of undernutrition, and in the benefits of this method for a better understanding of the physiology of undernutrition.

# SUMMARY

Body composition can provide insights into children's health and shows promise and exciting potential for improving the diagnosis of acute malnutrition and its treatment for an improved and longer term effectiveness. BIA is one way to estimate body composition. It is becoming easier to study since new methods have been developed, making the measurement quicker, easier and more reliable for field practitioners to perform in otherwise challenging settings.

Because of its potential in providing important information on the true physiological status of malnourished children, body composition measurement should be systematically incorporated into research projects aiming to test the effectiveness of current or new diagnostics or treatment methods. Body composition data is also crucial in informing the long term health of children, an area that deserves much more attention. Finally, among edematous children, BIA measurements could provide insights on the distribution and extent of fluid imbalance and help optimize the treatment of this particularly vulnerable malnourished group.

While BIA is relatively simple to measure it does require cooperation from the patient to remain calm and in a correct position, which is a challenge for young children. Particular attention and effort should be placed in standardizing a quality scale for BIA measurement in order to obtain valid results comparable across studies.

Despite its great interest and added value in research settings, BIA remains a method that cannot be applied yet in field routine programmes. More simple, reliable and straightforward interpretation methods are needed in addition to population specific and validated reference values.

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# BODY COMPOSITION IN SAM: WHY?

## CHILDHOOD UNDERNUTRITION

Child undernutrition is highly prevalent in low-income and middle-income countries and is recognised as a high burden disease accounting for 3.1 million child deaths every year (1,2). Black & *al.* estimated in 2011 that 45% of all child deaths were attributable to undernutrition, from foetal growth restriction to stunting, wasting and deficiencies in vitamin A and zinc (1). Worldwide, wasting; defined by a weight-for-height [WHZ] < -2 z-score; affects 50,5 million children under 5 and is estimated to be responsible for 875,000 (13%) child deaths each year (1,3).

From the age of 6 months, children suffering from Severe Acute Malnutrition (SAM) are identified by measuring their weight, height and MUAC (mid-upper arm circumference), and by assessing the presence of bilateral pitting oedema. Diagnosis of SAM for children aged up to 59 months is hence based on the three following indicators according to the 2013 WHO recommendations: 1) WHZ < -3 z-score; and/or 2) MUAC < 115 mm; and/or 3) confirmed bilateral pitting oedema (4,5). SAM children have a high risk of morbidity due to a weakened immune system resulting for instance in a 11,6 fold increased risk of death when their W/H ratio is < -3 z-score, compared to non-malnourished children (2). Timely and accurate detection and treatment of those children is therefore needed to prevent morbidity and mortality.

## TREATMENT OF SAM CHILDREN

Current treatment for SAM children aged 6 to 59 months consists of the provision of a systematic course of antibiotic, prescribing high-energy therapeutic foods providing macro & micronutrients allowing rapid catch up growth, and symptomatic treatment of simple child diseases such as malaria, diarrhoea, respiratory infections and skin lesions. This treatment is delivered at health centre level (outpatient) during weekly consultations, and then taken at home the rest of the week. Any medical complication identified lead to referral to an inpatient treatment where further examinations will take place and more treatment modalities will be provided to the child (5–7).

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## PHYSIOLOGY OF SAM: THE BLACK BOX

Knowledge on the physiological status of SAM children at admission, during treatment, at recovery, in adolescence and in adulthood is insufficient and limits the current effectiveness of programmes:

• Diagnosis and admission to nutrition programmes reflect nutritional status based on anthropometry rather than physiological aspects (i.e. to what extent poor nutritional status reflects the severity of fat-free mass and fat mass deficits, hydration status, and vice versa?);

•Similarly, effectiveness of treatment is defined by a child who has recovered based on anthropometric indices, weight or MUAC gain (5–7). This is reflected by nutritional status but is only a proxy for true physiological recovery (i.e. is fat-free mass deficit fully recovered in children who have reached WHZ or MUAC discharge criteria?);

• Physiological response remains poorly documented such as the type of weight gained by malnourished children during their treatment (6) (i.e. do SAM children gain more fat-free mass or more fat mass during their treatment with RUTF and do these proportions change along the treatment?);

• Long-term effects and quality of life of former SAM children is not sufficiently documented despite several studies suggesting possible negative consequences (i.e. SAM survivors showing thrifty growth patterns which are associated with potential risk of non-communicable disease, should other risk factors (e.g. obesity) manifest in later life (8)).

## POTENTIAL OF BODY COMPOSITION ASSESSMENT IN PEDIATRICS

Body composition assessment aims at quantifying body components: fat mass and fat-free mass in individuals (9). In pediatric diseases, body composition assessment has the following potential (10):

a. Could improve identification of children most at risk;
b. Could improve the monitoring of treatment progression and hydration status;
c. Could inform our understanding of physiological recovery regarding the nature of mass deposited: fat-free mass, fat mass;
d. Could predict risk for future non-communicable diseases (NCDs).

In fact, both the amount and distribution of body fat as well as the amount and composition of lean mass, are understood to be important health outcomes in infants and children. Almost all diseases impact body composition in one way or another, affecting physiological function and health. Monitoring of body composition outcomes can therefore help in diagnosis, monitoring of diseases progression and their clinical management; either by identifying differences between groups or by determining responses to treatment in individuals (10). On one hand, the quantity and quality of fat-free mass is associated with functional organs and tissues and may also be important for immune function (11). On the other hand, excess body fat and its distribution in adulthood contribute to the onset of non-communicable chronic diseases such as type 2 diabetes and cardiovascular diseases (12). However, in children this relation is much less clear and it is generally thought that both excessive fat and too low of a fat store are deleterious (13). During recovery from malnutrition, both tissues are needed to re-establish a healthy body but to what extent each is required is still not known.

## BODY COMPOSITION IN SAM CHILDREN: WHAT MATTERS?

Exploring body composition in undernourished children has the following interests:

**1. Diagnosis of undernutrition should distinguish those at higher risk of death,** higher weight deficit, higher co-morbidities and allow for subsequent tailored treatments defined to fill the nutritional, physiological and anthropometric needs. Even though low values of WHZ and MUAC both identify children with increased mortality risk, there is discrepancy of diagnostic between these two indexes (6,14,15). Current thresholds do not systematically identify the same children i.e.: SAM children identified with WHZ<-3 do not consistently have a MUAC<115mm, and vice versa. Discussions about the current protocol used for SAM diagnosis focus on simplification and targeting children with highest risk of death. Which criteria, low WHZ or low MUAC, identify the children most at risk of dying? Grellety et *al.* found that MUAC<115 mm failed to identify a third of children who died (16). This raises concern on the fact that undernourished children in need of treatment could be missed when using one or another detection criteria.

→ The discrepancy between the 2 diagnostic criteria for SAM justifies the need to investigate other diagnostic methods to complement existing ones, to better identify those children most in need of treatment. Body composition provides interesting information that could be correlated with existing one, allowing better estimation of the risk of death. For instance, the OptiDiag project (**Annex 1**) investigates, among other innovative biomedical techniques, the body composition of SAM children in combination with traditional anthropometry (WHZ, MUAC) to compare vulnerability of SAM children.

**2. Identifying and monitoring the resolution of fluid imbalances in oedematous malnutrition**

Currently, in clinical practice, oedema is identified by pressing thumbs on the front of the feet and observing a pit in both feet after the thumbs have been removed (17). The resolution of oedema is monitored simply by measuring weight at admission and observing its temporary drop upon the resolution of the oedema (7). These methods do not allow the distinction between the type of water lost: whether extracellular or intracellular nor its quantity and distribution. Body composition measurement including total body water and extra and intracellular water quantification would come useful in the diagnostic and monitoring of the resolution of fluid imbalances in oedematous forms of malnutrition (18). As has recently been claimed for neonatal care, BIA has a lot of potential for improving the clinical care of these vulnerable babies (19).

### 3. Recovery should aim at true physiological recovery and consider the nature of weight gain in terms of fat versus fat-free mass deposited

To date, there are very few data on the progress of body composition in acute malnourished children from admission to discharge. It is only assumed and not precisely known if the current nutritional treatment provided re-establishes adequately both fat-free mass and fat mass deficits while also restoring adequate fluid distribution. Fabiansen et *al*. (2017) for instance demonstrated that most of the weight gained by moderate acute malnourished children during their treatment comprises fat-free mass (20). Another study however highlighted that recovered SAM children presented no excess in fat mass but a lower absolute fat-free mass compared to normal children from the same context (21).

→ These results could indicate that "cured" SAM children may be recovered according to anthropometric criteria but may still present inadequate body composition, which raises concerns about the adequacy of the nutritional treatment and discharge criteria currently used in nutritional programmes. There is no universal reference for the optimal body composition of children making it difficult to evaluate the success of the rehabilitation. Results from *Bawere et al* (2016) suggest recovered SAM children regain fat free mass as community controls but have a limited representability as they included only children > 24 months admitted and discharged with MUAC criteria. There is a need to investigate body composition of SAM children more globally to know more about their physiological recovery.

### 4. Treatment should aim at do no harm over the long term and to prevent NCD risk at adulthood

There is now consistent evidence that fetal and early postnatal periods are periods at risk for developing later type 2-diabetes, obesity and metabolic syndrome or non communicable diseases (NCD) (22,23). Fetal and/or infant undernutrition exposure during Nigeria famine was significantly associated with higher risk of hypertension and impaired glucose tolerance in middle-aged Nigerians (24). Some studies also associated rapid growth & weight gain during the first years of life with later higher BMI, obesity and coronary heart disease, especially in subjects who were thin at birth (25–28). However rapid weight gain seems particularly detrimental in later childhood but less so in early infancy (29). On the other hand, the short term benefits of rapid catch up growth should not be undermined as they might also protect the child from acute illnesses in childhood (30). The ChroSAM study conducted in Malawi demonstrated that SAM has lasting effects on growth (i.e.: increasing stunting), body composition (i.e. less fat-free mass than normal children after recovery) and physical functions (i.e. weaker handgrip) (8). Additional scientific evidence is however critically needed regarding subsequent health consequences of childhood acute malnutrition in adulthood.

→ We do not know if SAM has a long-term impact or if through better treatment, we could reduce that impact. This relates to the consequences of malnutrition on later health; but also regarding the long-term effects potentially resulting from the rapid weight gain during treatment of acute malnutrition. The humanitarian community needs to complement the '*saving life*' approach with a '*do not harm in the long-term*' one; by minimising the long-term effects of acute malnutrition as well as the potential exacerbating effects of its treatment on later health.

## METHODS ASSSESSING BODY COMPOSITION

• Body mass index (BMI) is a commonly used measure of nutritional status categorising individuals into underweight, normal weight, overweight and obese. Although useful for risk predictions and clinical practise, BMI does not differentiate between tissue types (lean versus fat) and thus cannot be considered a valid body composition measure (31).

• Techniques such as skinfold thickness and waist circumference are simple and quick measurements providing raw estimates on regional body fatness. However, they do not provide information on lean mass, nor very accurate total body fatness (31).

• Arm anthropometry is widely used as a proxy of nutritional status as it is non-invasive, cheap, quick, and most of the time easy to measure (32). Low Middle Upper Arm Circumference (MUAC<115 mm) is a good indicator of increased risk of morbidity and mortality in children (5) but while both regional and total body fat mass are relatively well predicted by MUAC (32), fat-free mass seems better predicted by weight-for-height z-scores (33).

• Some **more sophisticated techniques** have recently become more widely used in paediatrics such as dual-energy X-ray absorptiometry (DXA), air-displacement plethysmography, isotope dilution and bio-electrical impedance analysis (BIA) (31). Each have their advantages and limitations and all are currently limited in their lack of reference data for children's body composition although efforts are being made to produce such standards (31,34):

  ○ DXA allows the measurement of bone density and both fat and fat free mass but is not necessarily very accurate in disease states or with varying body compositions or in longitudinal follow up.

  ○ Air-displacement plethysmography measures body density and assumes constant density for both fat and fat free mass to predict body composition. In many disease states fat free mass composition may be disturbed and thus the equations are less valid.

  ○ Isotope dilution estimates fat free mass by measuring total body water and is thus inherently sensitive to imbalance in lean mass hydration status.

  ○ BIA allows the prediction of fat free mass via equations estimating total body water and similarly to isotope dilution technique is sensitive to errors in case of fluid imbalances.

Compared to other techniques, BIA has great potential as it could be used to measure distribution of water (intra versus extracellular) by using single-frequency current as well as composition of different parts of the body by segmental BIA measurements. The following sections will provide more detail to the BIA measurement.

• Action Against Hunger in Burkina Faso, Liberia and Bangladesh used BIA devices named "Nutriguard S" rented or purchased from Data Input, Germany.

# BIA TECHNIQUE: THE BASICS

Bio-electrical Impedance Analysis (BIA) is a non invasive and relatively simple assessment of body composition with a portable equipment rapidly generating information (35,36).

BIA allows the evaluation of the two main body components: fat mass and fat-free mass and also enables the assessment of total body water and its distribution within and outside cells, provided it is measured in subjects without significant fluid and electrolytes disorder (35).

BIA is a method consisting in measuring the electrical resistance in an organic body by applying a harmless electrical current of low amplitude and low and high frequencies, usually 50 khz, through the organism, via electrodes on the skin (36,37). The current is passed through cables connected to adhesive gelled electrodes localized on the hand, wrist, foot and ankle of the same side of the body (36,37) (figure 2). This method is called the tetrapolar ipsilateral measurement*.

Note that this briefing paper only discusses whole body BIA (see figure 1) (38).

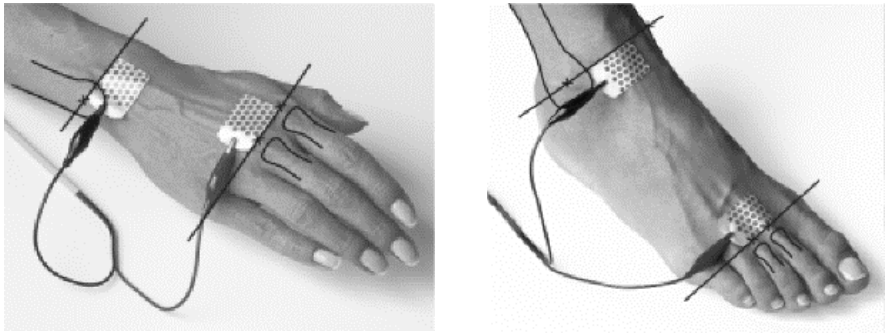

***Figure 2***: *Placement of electrodes on the hand and the foot*
*© Data Input, Nutriguard S instructions for use (37)*

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## *TETRAPOLAR IPSILATERAL MEASUREMENT

The patient should be measured in supine position with feet apart and arms not touching the side of the body. Contact between both legs or the arms and the torso can shorten the passage of the electric current and influence the results.

Placement of electrodes is for example determinant in obtaining quality results i.e. in children, a minimum of 3 cm between electrodes avoids interaction between them and increases chances to get good quality results.

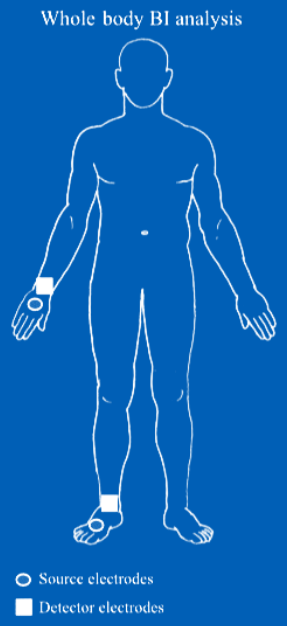


***Figure 1***: *Whole body BIA measurement, adapted from Mirele 2014*

## WHAT DOES BIA MEASURE?

The body responds to the electrical current by two different types of resistance:

- resistive resistance called **resistance (R)**
- capacitive resistance called **reactance (Xc)**

**Impedance (Z)** reflects the relationship between resistance and reactance and refers to the total resistance of a biological conductor measured in **Ohms** (35,37).

$$Z = \sqrt{R^2 + Xc^2}$$

This measure of impedance is needed in order to evaluate the total body water via an equation dividing individual's height by the impedance.

$$TBW = \frac{height}{Z}$$

Total body water measure is then used to estimate fat free mass quantity as shown below.

$$TBW = k1 + [K2 * \frac{HT^2}{Z}]$$

but sometimes also:

$$FFM = k1 + [K2 * \frac{HT^2}{Z}]$$

$$FFM = TBW \ / \ hydration \ fraction$$

Eventually fat mass is then calculated as the difference between total weight and fat free mass:

$$FM = Weight - FFM$$

Note that as such BIA never predicts FM, only TBW or FFM.

This calculation relies on constants k1 and K2 that vary substantially according to population. In particular in disease states that affect fluid dynamics this equation will present a looser association.

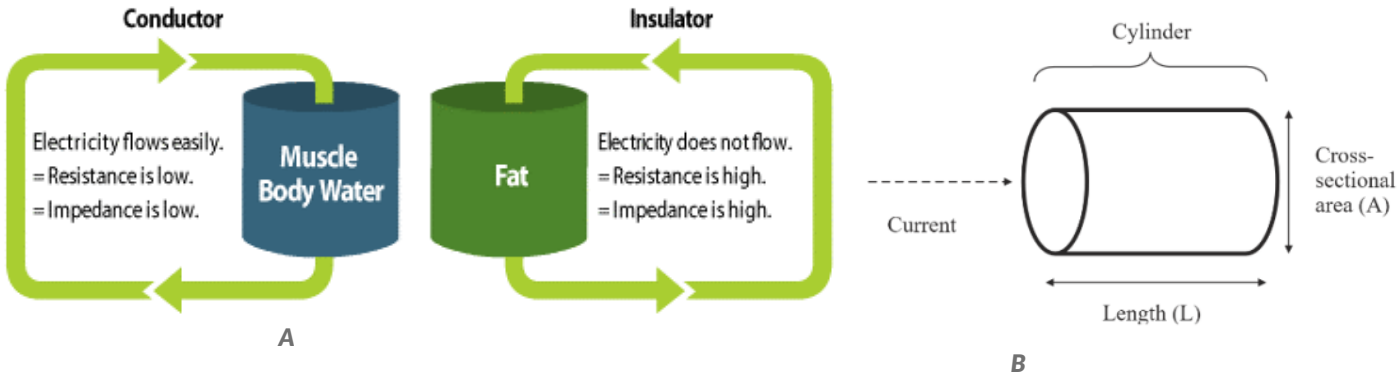


***Figure 3***: *B-Cylinder model for the relationship between impedance and geometry (Kyle & al. 2004)*

## → RESISTANCE (R)

Resistance (R) is the **opposition to the flow of an electrical current generated by extra and intracellular fluids** and is inversely proportional to total body water (TBW) and electrolytes concentrations (35,37). Lean mass for example has high content of water and electrolytes and hence is a good conductor of electrical current, showing low resistance and low impedance. On the contrary, fat, bone and skin are considered poor conductors (36,37). See below figure 3, A.

Resistance is also proportional to the length (L) of homogeneous conductive material of uniform cross-sectional area and inversely proportional to its cross sectional area - figure 3, B (35). The conventional BIA model considers the human body as a single cylinder to predict body composition (31). It is assumed that arm and leg segments reflect the general body composition, as they contribute to about 90% of total impedance (long length & short cross-sectional area = high resistance hence high impedance) (35).[3]

## → REACTANCE (Xc)

Reactance (Xc) is the **opposition to the flow of an electrical current produced by the cell membranes** (protein & lipid layers) briefly storing parts of the charge, acting as mini-condensers. Reactance hence reflects the measurement of the cell integrity (36,37).

[3] Note that other assumptions for correct estimation of BIA are homogenous composition, fixed cross-sectional area and consistent distribution of current density (39).

## BODY COMPOSITION COMPARTMENTS

As mentioned previously, in subjects presenting normal hydration and without major electrolytes disorder, BIA parameters (R, Xc and Z) are used to assess body composition compartments after being adjusted to height and combined with other physical and demographic variables such as age, body weight, gender, ethnic group, clinical situation, etc. (34,36).

All these parameters are then entered into **specific predictive population regression equations**, allowing the prediction of total body water which is then converted to fat-free mass (32,35).

These predictive equations assume that hydration of fat-free mass is normal, between 73% and 80% in an age appropriate manner.

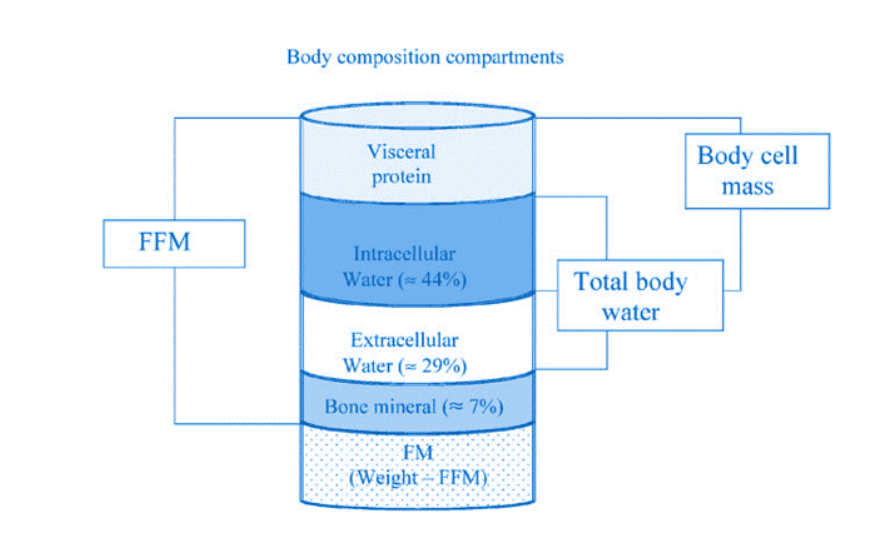


***Figure 4**: Schematic diagram of FFM, TBW, ICW, ECW and BCM. (Kyle et al. 2004)*

### Total Body Water (TBW)

TBW is the largest component of the body and is found exclusively in Free-Fat Mass (FFM) including non-fat components of both lean and adipose tissue such as interstitial fluid and blood vessels. It is around 80% at birth then falls in a non-linear manner to around 73% in adults. (35,36,40–42)

TBW = Intra Cellular Water (**ICW**) + Extra Cellular Water (**ECW**). In healthy adults, ECW space represents a relatively constant proportion of TBW, varying a bit in case of exercise or weight gain, and this can be assessed with 50 Khz single frequency BIA. The ECW/ICW ratio varies with age and in younger age groups there is no validated equation to calculate them.

### Free-Fat Mass (FFM)

This includes everything except body fat. FFM is determined by BIA population specific equations using TBW estimation, provided constant hydration of the body. FFM (kg) = TBW (kg) / 0.732.

### Fat Mass (FM)

Difference between body weight and FFM.

### Body cell mass (BCM)

Compartment rich in protein, including non-adipose cells & aqueous compartment of adipocytes. Loss of BCM is associated with poor clinical outcome.

## BIA EQUATIONS IN SAM CHILDREN: LIMITS AND ALTERNATIVES

Predictive equations of total body water or fat free mass using BIA can lead to inaccurate results when applied to subjects with different characteristics such as extreme BMI ranges or disturbed hydration status found in diseases such as liver cirrhosis, renal failure and cardiac insufficiency (43–46). In patients with malnutrition, BIA equations become inaccurate and potentially misleading because of disturbances in fluid and electrolyte balance (47,48).

**Currently it is not recommended to use body composition equations derived from BIA measurements in SAM children with edema.**

A study in Ethiopia showed that while BIA could well predict TBW in non-edematous SAM children the association broke down when children with edema were measured (48).

That is why the **use of raw BIA parameters is an interesting alternative** and is gaining greater attention for the assessment of body compartments in the most ill children. It circumvents equations and hence avoids algorithm-inherent errors and does not require assumptions such as constant fat-free mass hydration (39).

**Phase angle** and **Bioelectrical Impedance Vector Analysis** are more qualitative and visual methods overcoming those limits. They allow the analysis of body composition data in acute diseases such as SAM and provide information on hydration status, body cell mass and cell integrity (39). BIVA for instance provides qualitative information on how different the patients are from healthy children, whether they have edema, and can be used to monitor treatment progress. BIVA however cannot quantify FFM, FM and TBW compartments.

See section "Going further with Phase angle and BIVA" to know more.

# INSTRUCTIONS TO CONDUCT BIA MEASUREMENTS[4]

## PREPARE YOURSELF

**→ Identify the most appropriate BIA device & consumables**

- Device providing information on resistance, reactance at 50Khz;
- Resistance values should be measured up to 1,700 ohms, as previous research indicates that the most severe cases of malnourished children have resistance of near 1,700 ohms;
- Robustness of the device & suitability for the field i.e.: no computer needed to read raw BIA data during the measurement and sufficient autonomy of the battery;
- Available extra back-up batteries & extra sets of cables;
- Electrodes size adapted for children 6-59 months & possibility to cut it into half;
- Available anti-shock backpacks or other similar carrying bags for the device.

**→ Purchase required material in addition to the specific BIA device & electrodes**

- Disinfectant & cotton or baby wipes for cleaning the skin before placing electrodes;
- Mats and towels for cleaning the mat.

**→ Plan & budget staff required to conduct BIA measurements**

- Evaluate the need for staff to carry-out the measurements: usually 1 or 2 people are needed to handle the device and to read and note down the results upon measuring BIA;
- One measurement takes on average 10 minutes depending on the quietness level of the child;
- If BIA is implemented in health centres, the measurers can be the same people in charge of welcoming and taking anthropometric measurements.

[4] These instructions are based on Action Against Hunger experience in operational research with SAM children diagnosed with WHZ < -3 SD and /or MUAC < 115 mm in Burkina-Faso, Bangladesh and Liberia.

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**→ Calculate sample size at protocol stage**

- Consider that some measurements will be unsuccessful – 30% according to Action Against Hunger experience - due to challenges in making the children lie down still to obtain acceptable results i.e.: observer should discard data from the analysis when the protocol is not met (see standardization below);
- Measure as many children as possible.

**→ Standardize BIA measurements**

- Test and, if necessary, adapt the quality scale before implementation;
  **→ See technical note 1** for details on an example of a quality scale;
- If possible, conduct a validation study on the quality scale to compare different positions to the ideal and determine which ones yield acceptable results.

**→ Conduct training**

- Provide appropriate training to BIA measurers in regards to the quality scale chosen and to the calibration and preparation of the measurement. Training should include tricks for calming children so they lie in appropriate position;
  **→ See Technical note 2.**
- Develop clear standard operating procedures (SOPs) for the teams;
- Ensure teams get enough practice through a pilot study and through exercises addressing inter-observer error and within observer precision.

# TECHNICAL NOTE 1

## STANDARDIZE BIA MEASUREMENTS: DEVELOP YOUR QUALITY SCALE

***Prior to implementation:***
*Conduct field-testing & if possible validate a quality scale*

***During measurements:***
*Record the quality of each measure according to the scale*

***During analysis:***
*Discard all measures with low quality*

**Field-testing with the future target group is key in pre-identifying the possible positions that children may take so that a quality scale can be adapted to the observed variation.** If possible, a validation study should be implemented where a number of children take different positions and the deviation that these results give from the ideal position are considered and used as the basis in the development of validated BIA quality scale. The objective of the quality scale should be to ensure reproducible results within a child and across a study but also enabling the comparison of results between studies and in line with the theoretical guidelines.

Action Against Hunger developed the following quality scale as a result of standardization exercises and field-testing prior implementation of BIA. This scale however was not formally validated. For concrete pictures of children's positions during BIA measure & associated quality see *Annex 2*:

**1. Ideal: Limbs not touching & straight**
Child lying on his/her back, arms towards the lower body, straight elbows and legs, thighs apart, arms not touching the body, calm. All limbs resting on the ground.

**2. Good: Limbs not touching - very slight bends**
Small variations from the ideal position: slight bends in the knees or the elbows, but overall the child is lying flat, relatively calm and most importantly the arms are not touching the torso and the thighs are not touching each other either - no touching whatsoever.

**3. OK: Limbs not touching but bent**
Limbs separate, not touching, legs or arms maybe bent and/or arms until elbow on the ground but from elbow onwards possibly in the air or towards the upper body.

**4. Bad: Limbs touching**
Arms touching the torso and/or thighs or feet touching each other but child still at the moment of the measurement.

**5. Catastrophic: Child moving**
Child crying, moving, contracted, not laying on his/her back (sitting, or on the side), caretaker touching the child.

**TIPS**
→ Quality scale should be kept as simple as possible for the teams to use.
→ Some categories can be aggregated during analysis if deemed relevant.

**LIMITS**
**Such quality scale should be adapted to the context in which the research takes place but it would also be useful to have an international validated standardized scale to make results comparable across studies. This point requires further research and validation.**

ACTION CONTRE LA FAIM

# TECHNICAL NOTE 2

## TRAIN YOUR TEAMS: TRICKS TO RELAX CHILDREN

Below are some observations from Action Against Hunger in Burkina Faso & Bangladesh:

• Using toys was not the best trick to calm down children: they often try to catch it so their position keeps changing.

• In Burkina Faso, cartoon installed on the tablets and shown to children upon the BIA measurement made the children more frightened than relaxed whereas in Bangladesh using tablets was a successful experience.

• **Best option is to measure the children asleep**. In Burkina-Faso, caregivers of young children could be asked to hold the child onto their back for a while, and/or to breastfeed so that the child fell asleep and was placed on the mat, and then measured still.

• Measurers conducting BIA measurement should be **familiar with the child and seek to create an atmosphere of confidence** before starting the procedure (playing, talking with them) so the child feels more comfortable and relaxed.

**TIPS**

Tricks to relax children are **highly context dependent and should be tested** prior to implementation of BIA measurement.

***Figure 5**: Controlled and free options for BIA measurements - Bangladesh →*
*© Action contre la Faim, T. Dailey-Chwalibòg, Bangladesh 2017*

# TECHNICAL NOTE 3

## TEST OPTIONS TO MEASURE CHILDREN STILL

If a child is agitated during BIA measurement, the quality will probably be low and data should be discarded from the analysis. It can however be challenging to get children measured still especially with very young ones (< 2 years old) resulting in difficulties to obtain valid results and reducing the representativeness of the sample.

**In order to increase chances to get successful measurements**, a '**controlled option**' can be tested with adults or older children who can both behave and miss-behave to compare the effects: measuring them lying to determine whether it is feasible and how it affects the data to restrict their movements by holding their arms and feet still while protecting skin-to-skin contact. In order not to interfere with the electric current the measurer should wear a non-conductive cloth in his/her hands.

According to results, conduct field-testing with younger children and decide whether the controlled option can be used for getting more good quality measures.

**TIPS**

Any form of control should be **supported by data** obtained during field testing.

ACTION CONTRE LA FAIM

## IMPLEMENT MEASUREMENTS

**→ Calibrate BIA device**

- Implement a register for weekly calibration of BIA apparatus & weekly quality check of the electrodes (sandwich test with both electrodes put in contact).

**→ If BIA measurements are conducted in a health centre - organize the flow**

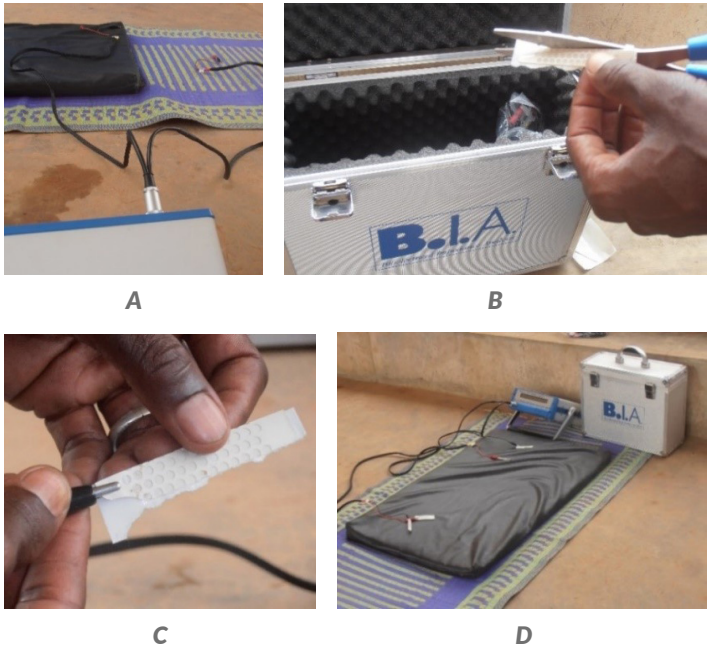
- Conduct BIA measurements before any activity that would frighten the children such as vaccination, so the children already know the staff and are less likely to be afraid.

**→ Explain the measure to the caregiver**

- Explain that this measure is completely harmless, painless and is quickly done. The objective is to learn more about the health status of the child, through a very weak electric current between electrodes placed on a hand and a foot, while the child is lying down. It will provide information on the quantity and distribution of water in the child's body.

**→ Prepare BIA materials**

- Mats, BIA device, cables and electrodes, tester for calibration, disinfectant, cotton.
- Prepare all materials in advance:
  - Electrode cables plugged to the device (A),
  - Electrodes cut in half lengthwise (B).
  - Distal edge of the electrodes attached to the electrode cables (C).
  - Attach the electrodes on the child's skin (D):




A B C D

***Figure 6***: *Preparation of BIA materials for measurements - Burkina Faso →*
*© Action contre la Faim, Sophie Renault, Burkina Faso, 2017*

**→ Prepare the children for BIA measurements**

- Relax the child according to tips identified during pilot phase. **→ See technical note 2.**
- With the help of a ruler and/or your fingers (2 adult fingers make 3 cm in width), make sure there is a 3 cm distance between electrodes and attach the electrodes to the same side of the body, on dominant hand, wrist, foot & ankle of the child. **→ See technical note 3** & *Annex 2* for more details.

**→ Conduct BIA measurements**

- Place the child in a horizontal position on their back. The child's legs should lie apart straight so that the thighs do not touch each other. The arms should rest alongside the body towards the lower limbs but not touch the rest of the body (see Figure 7). **Contact between legs or arms and the torso can shorten the passage of the electric current and produce unreliable measures** (37).
- Start the BIA device and take the measures as soon as the child lies relaxed. Measurer should not touch the child while measuring or it will influence the measures, unless 'controlled option' was validated before.
- The measure itself can be as quick as 10 seconds if the child is still. However the full procedure usually last from 4 to 10 minutes including the preparation, calming the child and reading the result on the device.
- Estimate and record the quality of all measures (ideal / good / OK / bad / disaster) according to the child's position and to the quality scale developed.
- Record the following values:
  - resistance (R)
  - reactance (Xc)
- Carry-out at least two consecutive measurements, at least 3 minutes apart, depending on your available time – in order to be able to calculate the average result.

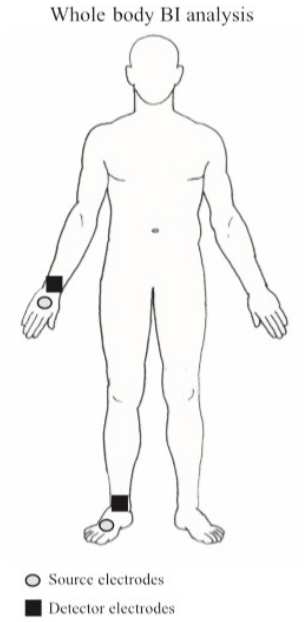




***Figure 7***: *Required position of patients during BIA, adapted from Mirele 2014*
***Figure 8***: *BIA device in use © Action contre la Faim, Sophie Renault, Burkina Faso, 2017*

# TECHNICAL NOTE 4

## MAKE SURE YOU CORRECTLY USE THE ELECTRODES

The **position and use of the electrodes is a key parameter to consider for the quality of the measure** in addition to the position of the children (ideal / good / OK / bad / catastrophic).

**→ Keep in mind** (37):

- *"Incorrect placement of the electrodes by only 1 cm can lead to a difference in calculation of 20 Ohms, which is equivalent to 1 liter of body water".*
- *"For children, the distance between the electrodes should be at least 3 cm. If the difference is less this can cause an interaction between the electrodes. For especially small hands ie. children's hands the electrodes can be halved lengthways".*
- Surface contact between electrode and skin should be > 4 $cm^2$.

**1. Respect the size of the electrodes & the contact surface with the skin**

In SAM children, because of their tiny hands, electrodes may still be too close (< 3 cm) even cut in half lengthways, which is likely to impair observations. In order to respect both distance between electrodes and minimum contact surface between electrode and skin (> 4 $cm^2$), you can also **extend the distance between electrodes** by moving the electrode located around the wrist in direction of the arm (Figure 9). Results are more precise as the area of the electrode in contact with the skin is bigger.

**2. Standardize the side of the measurements**

Since young children have not yet fully developed their dominant side muscles, it does not make a difference whether the measure is conducted on dominant or non-dominant side. The most important is to **standardize the side of electrodes in all children measured (right of left).**

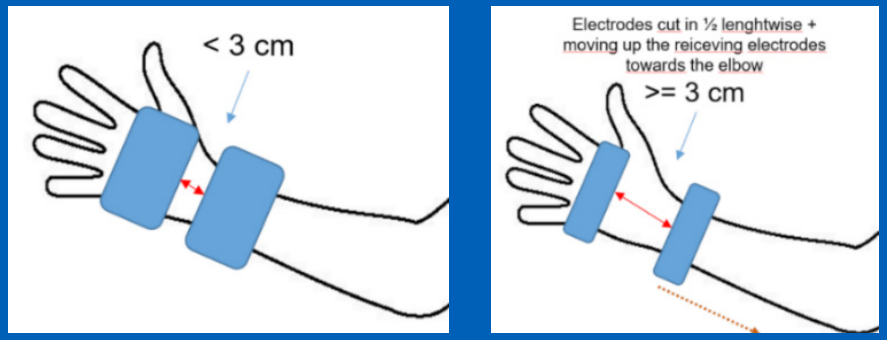



***Figure 9**: Scheme of hand electrodes ←*

**TIPS**

**Distance between the two electrodes can be assessed using a ruler or two fingers** (index & middle finger), or visually after more practice.

ACTION CONTRE LA FAIM

## MONITOR BIA MEASURES & MATERIALS

### → Monitor success rate & quality categories

- Monitor the percentage of successful BIA measurements on a weekly basis, as well as proportion of each quality category recorded (ideal / good / OK / bad / disaster).
- Consider regular field visit supervisions to ensure that the quality of the measurements recorded are in line with the standardized quality scale to prevent any systematic mistake in classifying the position of the children.
- If several teams are conducting BIA measurements, mix them so they can share best practises in calming the children and also agree on the quality scale.

### → Maintain BIA material

- Check the quality of the electrodes with the sandwich test.
- Calibrate the device with the TE test measure.
- Charge batteries according to the producers' technical recommendations.

### → Precision and Inter-observer error exercise

- Perform a quality control on the precision of the method, for example, by measuring 10 children, twice each per observer and by all observers. Enter all the data into a spreadsheet and do an analysis of variance. Ideally, the only significant term will be the child, and both observer and duplicate will be insignificant. Using appropriate statistical tests, you can identify which observer is different to any other and apply appropriate correction measures.

## WHAT IS PHASE ANGLE?

→ Phase Angle (PA) is an indicator obtained from BIA measures and is derived from resistance (R) and reactance (Xc). It is expressed as

$$PA = \arctan\left(\left(\frac{R}{Xc}\right) * \frac{180}{\pi}\right)$$

(Norman et al. 2012):

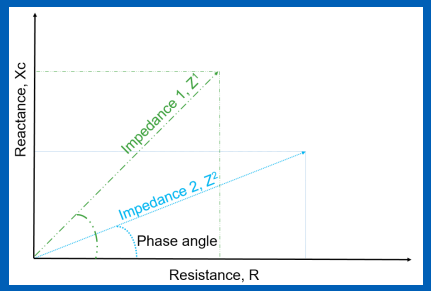



***Figure 10**: Graphical representation of impedance and phase angle [adapted from Barbosa et al. 2005]*

→ Phase angle reflects electrical properties of tissues affected by disease, nutritional and hydration status, **expressing the amount cell mass and hydration status hence a potential indicator for cell membrane function.**

→ In healthy subjects, phase angle for example decreases with age i.e. ageing is associated with loss of muscle mass which is reflected by reduced reactance; decreased body water is reflected by higher resistance - at the expense of increased proportion of fat mass which does not contain water hence leads to higher resistance.

Lower blue phase angle above in figure 10 could be found in older subjects compared to the higher green phase angle (higher reactance = higher cell membrane integrity & lower resistance = better cell hydration).

# GOING FURTHER WITH PHASE ANGLE & BIVA

Both Action Against Hunger MANGO & OptiDiag projects are not yet in data analysis stage. The following part is thus a non-exhaustive review of information on Phase Angle & BIVA.

## WHY IS PHASE ANGLE RELEVANT IN DISEASES?

Phase angle is considered as an important prognostic, nutritional, membrane cell function, or health marker in various clinical conditions such as cancer, HIV, dialysis, liver cirrhosis, and others (39,49,50). Low phase angle has been associated with poor prognosis, nutritional risk or progressing malnutrition, shorter survival time, length of stay, and could be considered as a useful tool for screening patients most at risk at admission (49–51). *Barbosa et al.* considered low phase angle as a general indicator of sickness; with higher value representing better cell function (39,49).

## PHASE ANGLE AND CHILDHOOD MALNUTRITION

There are to date few studies directly exploring phase angle in SAM children. A recent study conducted in Ethiopia however indicated that SAM children had lower reactance and lower phase angle compared to healthy children and that phase angle increased with MUAC (52). Reactance, resistance and phase angle were all lower in edematous children compared to non-edematous SAM children (52). Reactance was the highest in healthy children and the lowest in edematous children indicating altered cell membrane integrity in SAM and especially in edematous SAM (52). Another study conducted in Japan highlighted that phase angle was also significantly lower in malnourished children and increased in most cases during or after nutritional management together with reactance, body weight, arm muscle circumference and serum albumin concentration, while resistance decreased (53). Such studies suggest that phase angle could be an interesting tool for prognostic and for monitoring recovery.

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## WHAT IS BIVA ?

→ **BIVA** is another approach allowing a qualitative measure of body composition without the need of equations or models to estimate fat-free mass and fat mass. It only requires raw impedance parameters.

→ Resistance (R) and reactance (Xc) standardized for height are plotted as point vectors on a "**RXc graph**" (figure 11). This method has the advantage to provide **visual information**, with the vector's length and position, on **hydration, body cell mass and cell integrity**, independently from body size and body weight.

→ BIVA also allows comparison of an individual vector with **reference data**, pictured by 50, 75 and 95% tolerance ellipses calculated in healthy population with similar characteristics (sex, age, ethnicity, etc.).

Comparison with reference values and migration of points allow visual change in tissue hydration and quality of soft tissue > see figure 11 below.

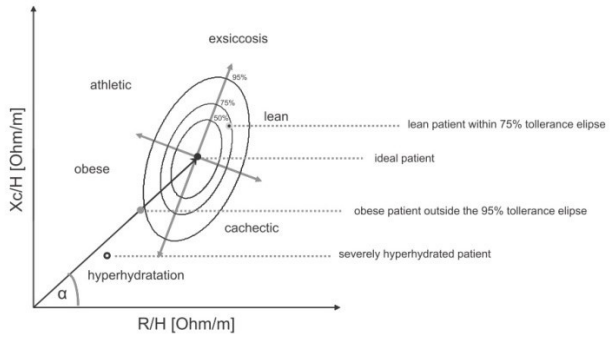
## WHY IS BIVA RELEVANT IN DISEASES ?

*Piccoli et al.* demonstrated that impedance vector was significantly shorter in both obese and renal patients compared to the healthy population (54). Other clinical evidence highlighted the interest of BIVA for monitoring hydration status in patients undergoing chronic hemodialysis (46), patients with liver cirrhosis (55), critically ill patients (56) and obese patients (58). However, a recent study by *Wells et al.* (2018) also questioned BIVAs capacity to predict fat free mass among normal children and adolescents (58).

## BIVA AND CHILDHOOD MALNUTRITION

In the sickest children, BIA is best used as BIVA, providing qualitative information on how different the patients are from healthy children, and whether they have oedema, and the technique can then monitor treatment ; but it cannot assess free-fat mass and fat mass in kg neither total body water in litres (54).

Studies exploring BIVA in acute malnourished children are rare but the method's potential to provide information on the severity of marasmus or edema at admission and hence on vital prognostic, as well as in monitoring physiological recovery through hydration status especially for inpatient is promising and deserves further attention (47).




*" Different positions of the vector indicating different body composition can theoretically produce comparable phase angles. Longitudinal changes in hydration and cell mass are therefore* ***interpreted more reliably by BIVA than phase angle alone.*** *"*

***Figure 11*** *: RXc graph from Norman et al. 2012*

ACTION CONTRE LA FAIM

# HIGHLIGHTS FROM ACTION AGAINST HUNGER'S EXPERIENCE

Below are highlights from Action Against Hunger's experience using BIA in the MANGO and OptiDiag research projects.

- **Simple measure but no straightforward interpretation**

  - Despite the time and patience needed for the preparation of the measurement in order to relax the children, the **measure itself is easy** as it is directly provided by a device and does not require reading such as for the height;

  - However, contrary to other measures such as height, weight and MUAC, there is **no possibility to understand and interpret raw BIA values** collected in a straightforward manner. It can therefore be somewhat frustrating for the teams to collect data they do not understand.

- **Quality of the measure**

  - Regular supervision & switches between measuring teams allows the detection of common mistakes such as miss-classification of the child's position and thus better standardization of the measurements;

  - Success of the measure can also be correlated to the age of the children: the youngest are often the most difficult to measure because of uncontrolled movements i.e.: some young children tear off the electrodes or turn to the side;

  - The second measure can allow a better quality result if the child becomes progressively quieter. However in some cases the opposite is true when the child starts getting more restless. The best approach is to wait and get the child asleep so that the limbs can be positioned ideally and the child remains still for long enough for 2 measurements.

- **Adaptation to different settings**

  - BIA measurements can be implemented in health centres but also at home level i.e. Action Against Hunger conducted BIA measurements during a SMART survey in Liberia at home with the help of the mothers. It is possible to use local plastic mats combined with small, very light mats with plastic cover (figure 12, A). Children should not sink into the material as this may affect BIA data.

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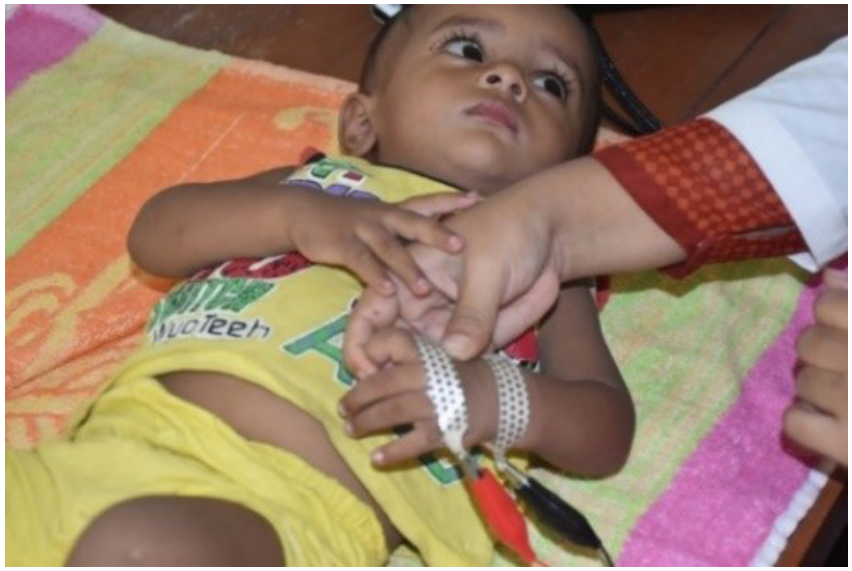
A

B



C

***Figure 12***: *BIA real settings in Burkina Faso (A), Liberia (B) and Bangladesh (C) - pictures B & C do not display ideal positions.*
*Photo A: © Action contre la Faim, Mango. Lagafou, Burkina Faso, 2018, Photo B: © Action contre la Faim, T. Dailey-Chwalibòg, Liberia, 2017 , Photo C: © Action contre la Faim, T. Dailey-Chwalibòg, Bangladesh, 2017*

# CONCLUSIONS & WAYS FORWARDS

The points below consist in a summary of the lessons learnt by Action Against Hunger prior and during implementation of BIA measurements on SAM children, as described in this briefing paper.

**1. The method needs refinement**

- Before implementation, a **quality scale** needs to be settled reflecting the possible deviation from the optimal position taken by children during the measurement. Ideally this scale should be validated so that it could also be used in other studies resulting in comparable results across studies. This point requires further research and development.

- The **main challenge** of measuring BIA in children is managing to **keep them calm** during the measure which only lasts a few seconds if they are quiet. The quality of the measure depends mainly on how calm the child is and alternatives in the method could be explored in order to have higher proportions of successful measures in younger children i.e. segmental BIA could be further explored to determine if it can provide good identification of children at risk and of recovery; measure could be done on one arm only, etc.

- Currently, **BIA devices suitable for children do not allow straightforward interpretation of the body composition**. Collecting data on healthy children from the same context is necessary to analyse body composition with BIVA, which is promising but still quite experimental. More research with quality standardised BIA measures in SAM children is required to develop BIA standards and facilitate analysis and comparison across studies.

- With growing interest towards BIA, **simpler but more advanced devices are expected to be developed**, making interpretation of BIA data possible right after the measurement i.e.: device providing height data & BIVA values and graphs.

- Finally, with more interest towards BIA, it is also expected that prices of devices become cheaper making BIA measurement affordable for operational research studies.

**2. BIA should be promoted for operational research in SAM but not yet for routine nutrition programmes**

- BIA measures can and should be embedded in operational research in order to gain further understanding of the physiological needs of malnourished children. Research investigating the treatment effectiveness, physiological status and response to treatment of SAM children, their long term health as well as inpatient treatment success among oedematous children are the most obvious types of research programmes that would benefit from the additional information that body composition measurement provide.

- However it is not yet appropriate to use BIA in routine nutrition programmes: additional material & training is needed and data interpretation is not straightforward so the added-value of routine BIA cannot be yet ascertained.

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# ANNEX 1 : MANGO & OPTIDIAG RESEARCH PROJECTS

AAH included body composition measurements in two ongoing operational research projects:

• **MANGO** > **M**odelling an **A**lternative **N**utrition protocol **G**eneralizable to **O**utpatient care : a randomized controlled non-inferiority clinical trial aiming at testing the efficacy of an optimized RUTF dosage for uncomplicated SAM children in Burkina-Faso.

Underlying assumption is that the standard RUTF dose actually generates a surplus when administered at home in the context of other family members and household diets. Children may not consume the entire ration. Unless caregivers are sharing a fixed proportion of the amount whatever is provided, it is expected that children receiving reduced dosage will finally consume the same amount of RUTF compared with children receiving standard ration. If this assumption is true, the average weight gain may not differ between children receiving standard dosage and those receiving a reduced dosage ; but quality of weight gain and type of tissue deposited may differ.

The effectiveness of the reduced dosage will therefore take into account the physiological recovery in terms of fat-free mass deposited.

→ To know more : https://www.actioncontrelafaim.org/projet-mango/

• **OptiDiag** > **Opti**mized **Diag**nosis and Monitoring of SAM : Elucidating the heterogeneous diagnosis of SAM by current anthropometric criteria and moving beyond ; in Burkina-Faso, Liberia and Bangladesh. WHO recommends two anthropometric tools, mid-upper arm circum ference (MUAC) and weight-for-height Z-score (WHZ) to diagnose SAM in children aged 6 – 59 months.

However, the use of MUAC only for diagnosis, and the abandonment of WHZ, is increasingly applied. Doing so restricts the humanitarian target, disqualifying WHZ SAM children (46.7% globally) from access to treatment. The rationale for this is based on practical arguments on the ease-of-use of MUAC compared to WHZ and backed by scarce scientific evidence. There is a crucial need to confirm or infirm this paradigm shift, and to provide scientific evidence identifying children most in need of treatment.

This project aims to couple innovative biomedical techniques with traditional anthropometry to compare the vulnerability of SAM children using MUAC and WHZ. It will fill the research gap allowing policy makers to decide on the appropriate diagnostic tool to identify malnourished children most in need of treatment.

The OptiDiag project will also help generate new algorithms to assess and classify SAM children based on combined use of emerging biomarkers and traditional anthropometry. Finally, our innovative research will help assess the power of current treatment regimens to promote weight gain, growth and tailor treatment to the needs of children.

→ To know more :
https://www.actioncontrelafaim.org/en/optidiag-project/

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# ANNEX 2: EXAMPLES OF CHILDREN'S POSITION DURING BIA MEASURE & QUALITY ACCORDING TO AAH SCALE

**Bangladesh**
Quality of this measure is **ideal**:
No bending, no touching, legs lying apart at an angle of approx. 45° and approx. 30° between the torso & the arms.

*© Action contre la Faim, T. Dailey-Chwalibòg, Bangladesh, 2017*

**Liberia**
Quality of this measure is **bad**:
Right arm touching the torso, left arm & legs very bent.

*© Action contre la Faim, T. Dailey-Chwalibòg, Liberia, 2017*


**Burkina Faso**
Quality of this measure is **OK**:
No touching – legs.

*© Action contre la Faim, Mango. Lagafou, Burkina Faso, 2017*

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# OPERATIONAL RESEARCH

## MEASURING BODY COMPOSITION IN MALNOURISHED CHILDREN USING BIOELECTRICAL IMPEDANCE ANALYSIS (BIA) METHODS

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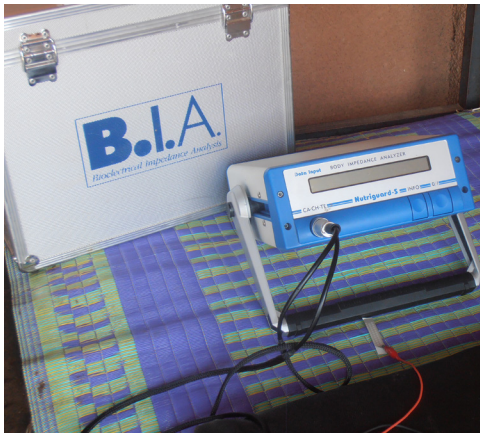
### 1. CHOOSE THE MOST APPROPRIATE BIA DEVICE




Device providing information on **resistance, reactance and phase angle at 50Khz**

- Resistance value measured up to 1,700 ohms, as previous research indicates that most severe cases of malnourished children have resistance of near 1,700 ohms

- Robustness of the device & suitability for the field i.e.: no computer needed to read raw BIA data during the measurement, robustness to heat and humidity

- Electrodes size adapted for children 6-9 months & possibility to cut it into half

### 2. STANDARDISE BIA MEASUREMENTS

**Conduct field tests in children** to determine which position yield acceptable results and develop a validated quality scale for the research:

- **IDEAL**: limbs separate not touching and straight, arms towards the lower body, all limbs resting on the ground

- **GOOD**: limbs separate not touching, legs or arms maybe slightly bent

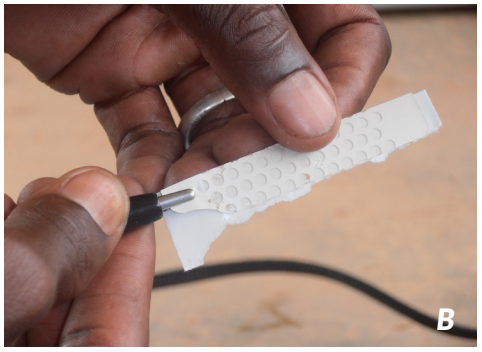
- **OK**: limbs separate not touching, legs or arms maybe slightly bent and/or arms until elbow on the ground but hands and lower arms may be in the air upwards or downwards

- **BAD**: arms touching the body and/or legs or feet touching each other

- **DISASTER/CATASTROPHIC**: child is inclined to the side or moving a lot, cries hard and is contracted, caregiver touches the child.

### 3. PREPARE ALL MATERIALS IN ADVANCE

- Electrodes cables plugged to the device **(A)**
- Electrodes cut in half lengthwise **(B)**
- Distal edge attached to the electrodes **(C)**
- The remaining step is to attach the electrodes on the childs' skin **(D)**



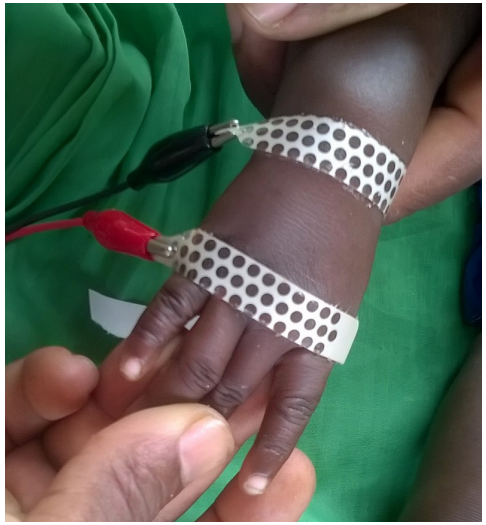

### TAKE THE FOLLOWING INTO ACCOUNT DURING PROTOCOL DEVELOPMENT:

**SAMPLE SIZE** : Consider +30% for sample size estimation to allow for final analyses on good and ideal measurements only.

**MEASURERS TRAINING**: Provide appropriate training on the developed quality scale, based on standard operating procedures.

**PRACTICE** : Conduct a pilot phase to allow practice before measuring children for good.

## 4. CORRECTLY USE & PLACE ELECTRODES



• Cut electrodes in half lengthwise so the **required minimum distance of 3 cm between the 2 electrodes is respected** to avoid interaction between the electrodes and therefore impaired observation.

• Make sure the whole length of the electrode is attached to the skin so the **contact surface between the skin and the electrode is >4 cm²** (as specified in BIA device guidelines) - results are more precise as the area of the electrode is bigger.

• If needed, **extend the distance between the electrodes by moving a little the wrist electrode upper towards the elbow**, to respect the 3 cm distance between the 2 electrodes and the contact surface between the skin and the electrodes.

• Check **hand and foot resistance values (must be <250 Ohms)** as quality check of the adhesiveness of the electrodes and therefore the quality of the measure.

## 5. CONDUCT BIA MEASUREMENTS

• Place the child on the back. The child's legs should lie apart at an angle of approximatively 45°. The arms should rest at an angle of approximatively 30° and not touch the rest of the body. **Contact between both legs or the arms and the torso can shorten the passage of the electric current and produce unreliable measures.** See more technical information in Annex 1.

• Start the device as soon as the child is relaxed and read the measurement when it appears on the device screen. **The full BIA measurement usually lasts from 4 to 10 minutes**, for two measures If the child is still, one measure takes 15 seconds in average.

• Conduct at least **two consecutive measures.**

• Record the quality of both measures (disaster / bad / OK / good / ideal).

### WHAT IS THE BEST OPTION TO RELAX THE CHILDREN BEFORE BIA MEASURES ?

• Measure the children asleep.

• The measurer should be familiar with the child and seek to create an atmosphere of confidence before starting the measure.

• Using toys to calm children might not work as children often try and catch the toys.

### FEEDBACK FROM THE TEAMS CONDUCTING BIA MEASUREMENTS

• The measure itself is easy as it is directly provided by a device and does not require reading such as for the height.

• There is no possibility to understand raw B.I.A values collected in a straightforward manner. It can therefore be a bit **frustrating for the teams to collect data they do not understand.**

• Risks of over estimation of the quality between 2 'good' & 3 'OK' as the only difference lies in the degree of bending.

• **Success of the measure is correlated to the age** of the children : the youngest the more difficult to succeed because of movements.