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Clinical tools to assess nutritional risk and malnutrition in hospitalizaed children and adolescents

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Abstract. – Malnutrition in children and adolescents may be underestimated during hospital stay. In western countries, children were often hospitalized for acute or chronic diseases that are not necessarily related to malnutrition. However, acute or chronic injuries may hamper nutritional status, prolonging recovery after admission and consequently length of hospital stay.

Several methods and techniques are known to investigate malnutrition in children, even if their use is not widespread in clinical practice. Many of these are simple and easy to perform and could be useful to a better management of every kind of illness.

In this review, we will focus on clinical tools necessary to reveal a nutritional risk at admission and to assess nutritional status in hospitalized children and adolescents.

Key Words
Nutritional risk screening tools, Malnutrition assessment, Hospitalized children.

Introduction

An adequate nutritional state plays a crucial role in normal growth, treatment response, comorbidities, quality of life, cost of care and long-term survival among pediatric hospitalized patients with clinical conditions[1]. In 2013, the Academy of Nutrition and Dietetics and American Society of Parenteral and Enteral Nutrition (ASPEN) defined pediatric malnutrition as "an imbalance between nutrient requirements and intake, resulting in cumulative deficits of energy, protein or micronutrients that may negatively affect growth, development and other relevant outcomes"[2].

In pediatric patients, the illness-related malnutrition is a dynamic and multifactorial process sustained by several factors such as inflammation, nutrient losses, increased energy expenditure, decreased nutrient intake or utilization. These conditions may be related to acute (trauma, burns, infections) or chronic diseases (cancer, chronic kidney diseases, cystic fibrosis, heart failure, inflammatory bowel diseases, neurological and neuromuscular diseases, etc.)[3-8].

Pediatric illness-related malnutrition is yet an undervalued issue, even if abnormalities of nutritional state may produce significant morbidity and mortality among pediatric patients and several studies have reported a prevalence of 6%-51% of this condition among hospitalized children[9,10].

Consequently, an accurate screening of nutritional risk and an appropriate assessment of the nutritional state may be crucial for the clinical management of these patients. In hospitalized children, a prompt nutritional intervention on body composition is useful to reverse linear growth arrest, promote tolerance to therapeutic regimens, improve the quality of life and reduce the length of hospital stay (LOS)[11,12].

The European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Society for Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) recommend nutritional risk screening for hospitalized children during admission, to facilitate the detection of children nutritionally at risk and to allow the physician to make an appropriate nutritional support plan[13]. Even if several pediatric nutritional risk scores are reported in literature, there is not consensus on the "ideal" screening tool and, often, nutritional screening is not yet widely performed[14].

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A complete nutritional assessment requires at least five steps[2,15]:

- Medical and dietary history;
- Detailed physical examination;
- Biochemical parameters;
- Accurate anthropometric measurements (weight, height, weight for height [WFH], head circumference, body mass index [BMI], mid-upper-arm circumference [MUAC], triceps skinfold [TSF] thickness);
- Body composition measurements.

Besides, body composition analysis requires the evaluation of fat mass (FM), fat-free mass (FFM) and body cell mass (BCM)[16]. Several methods are available for this purpose[17-19].

In this review, we describe nutritional tools reported in scientific literature for the screening and the diagnostic assessment of nutritional status among hospitalized children and adolescents.

Nutritional Risk Screening Tools

According to ESPEN statements, nutritional risk screening tools have been designed to detect protein and energy undernutrition and/or predict if undernutrition may develop or worsen[20]. An appropriate nutritional screening tool may inform about patient's nutritional status and its relation to patient's illness. By definition, a nutritional screening tool should be not time-consuming, simple, easily comprehensible, sensitive and specific, applicable and reliable for a wide disease group and in the daily practice[21].

To date, in our knowledge, there are seven main nutritional risk screening tools available for children[22,23] as listed in Table I.

Firstly, in 1995 Reilly et al[24] proposed the *Nutritional Risk Score (NRS),* based on four items: Body Mass Index (BMI), weight loss in the last 3 months, dietary intake in the last week, severity of the disease. NRS is simple to use and applicable to all medical and surgical patient categories and ages, for assessing risk of undernutrition at admission to the hospital and for identifying need of nutritional intervention

The *Pediatric Nutrition Risk Score (PNRS)*, proposed in 2000 by Sermet-Geydelus et al[25] analyses three items: patient's medical condition (valuated from 1 to 3 points according to the presence of mild, moderate or severe disease), presence of pain (1 point if pain is present), reduction of food intake (1 point if food intake is <50%). A score ≥3 indicates that the patient is at high risk of malnutrition and must be referred to a nutrition team. This method is rather quick, but it does not identify the nutritional status of the patient[23,25].

Secker and Jeejeebhoy[26] proposed the Subjective Global Nutritional Assessment (SGNA) in surgical patients between 1 month and 18 years of age within 30 days after a surgical intervention. Anthropometric measurements (length or height, weight, percentage of ideal body weight for height, body mass index-for-age, MUAC, TSF, mid-arm muscle area, handgrip strength), biochemical investigations (concentrations of serum albumin, transferrin, and hemoglobin and total lymphocyte count), parental height, dietary intake, GI symptoms, functional status of the patient and physical exam were assessed. Patients are divided into three groups: well nourished, moderately malnourished, severely malnourished. So classified, malnourished children had higher rates of infectious complications and a longer post-operative LOS than well-nourished children[23,26]. This method allows a nutritional evaluation of hospitalized children who may be at risk of malnutrition, although it is lengthy and time-consuming[27].

McCarthy et al[28] validated the *Screening Tool for the Assessment of Malnutrition in Pediatrics (STAMP)* in a study performed in the United Kingdom among medical and surgical patients between 2 and 17 years of age. The score evaluates patient's clinical diagnosis, nutritional intake during hospitalization and anthropometric measurements, developing a care plan based on the child's overall malnutrition risk (low, medium or high). STAMP is reported to have a high specificity (90%) and sensitivity (72%) in identifying malnutrition risk[23,27].

Gerasimides et al[29] adopted the Pediatric Yorkhill Malnutrition Score (PYMS) in the United Kingdom among medical and surgical patients between 1 and 16 years of age. The PYMS assesses four items: BMI, history of recent weight loss, changes in nutritional intake and the expected effect of current medical condition on patient's nutritional status. The total score reflects the degree of the patient's nutritional risk. PYMS reported a moderate sensitivity (59%), a high specificity (92%) and fewer false-positive cases than STAMP score[23,27].

In a multicenter study conducted in Netherland among medical and surgical patients between 1 month and 18 years, Hulst et al[30] proposed the *Screening Tool for Impaired Nutritional Status and Growth (STRONGkids).*

Table I. Main nutritional risk screening tools for hospitalized children.

Tools	Authors	Population	Age	4 Main principles items according to ESPEN[20]				Other items	
				Current nutritional status	Weight loss	Reduced intake	Disease severity	Anthropometric measurements	Signs and symptoms
NRS[24]	Reilly et al, 1995	Medical	0-17 years	x	x	x	x	x	
PNRS[25]	Sermet-Geydelus et al, 2000	Medical and surgical	>1 month-18 years	x		x	x		Pain
SGNA[26]	Secker et al, 2007	Surgical	>1 month-18 years	x	x	x	x	x	GI symptoms, functional capacity, parental height
STAMP[28]	McCarthyet al, 2012	Medical and surgical	2-18 years	x		x	x	x	
PYMS[29]	Gerasimidis et al, 2010	Medical and surgical, except cardiologic, renal, orthopedic conditions	1-16 years	x	x	x	x	x	
STRONG kids[30]	Hulst et al, 2010	Medical and surgical	>1 month-x 18 years	x	x	x			
PNST[35]	White et al, 2016	Medical and surgical	0-16 years	x	x	x			

NRS: Nutritional Risk Score; PNRS: Pediatric Nutritional Risk Score; SGNA: Surgical Global Nutritional Assessment; STAMP: Subjective Global Nutritional Assessment; PYMS: Pediatric Yorkhill Malnutrition Score; STRONGkids: Screening Tool for Risk of Impaired Nutritional Status and Growth; PNST: Pediatric Nutrition Screening Tool.

It consists of four items: subjective clinical assessment, high-risk diseases, nutritional intake and losses, weight loss or poor weight gain. Patients classified at high nutritional risk have a longer hospitalization and a negative standard deviation score (SDS) for weight-for-height (WFH), which indicated a state of acute malnutrition. This tool appeared rapid and easy-to-use (it needs a mean of three minutes); additionally it may predict LOS and identifies a need for nutritional interventions during the hospitalization. Huysentruyt et al[31] in a large Belgian population of hospitalized children, demonstrated the reproducibility of *STRONGkids:* a good correlation between *STRONGkids* score and the patient's current nutritional status (defined by WFH and SDS) was found, thus identifying patients needing a nutritional intervention during hospitalization.

Joosten et al[21] analyzed the six nutritional screening tools mentioned above, concluding that *STRONGkids* may be considered the quickest, reliable and practical to use, compared to others. In fact, it can be performed at the admission by every health care professional; it is based on a subjective clinical assessment without anthropometric measurements or additional items.

Conversely, in a multicenter study performed in 12 Italian hospitals, Spagnuolo et al[32] pointed out that notwithstanding its feasibility and sensitivity, STRONGkids is not specific. Consequently, it may be used as a very preliminary screening tool to be integrated with other clinical data.

Moeeni et al[33] compared the use of *STAMP, PYMS,* and *STRONGkids* for assessing nutritional risk among 150 Iranian hospitalized children. They demonstrated that *STRONGkids* correlates better than the others with the anthropometric measurements and with LOS. The same group showed similar results in a pediatric population of New Zealand[34]. On the other hand, Wonoputri et al[27] recommended *PYMS* as the most reliable screening tool in hospitalized children in Indonesia.

Recently, White et al[35] proposed the *Pediatric Nutrition Screening Tool (PNST)*, based on 4 simple nutrition screening questions: involuntary weight loss in recent days, poor weight gain in the last few months, reduction in food intake in the last few weeks and presence of obesity.

Nutritional risk is assessed by the presence of almost two positive answers to the above-mentioned questions. *PNST* may provide a sensitive, valid, and simpler alternative to existing pediatric nutrition screening tools such as *STAMP*, *STRONGkids*, and *PYMS*.

Even if several studies have been conducted for evaluating these various nutritional screening tools, at present, there is not yet a consensus on any tool as in the adults.

In 2015, Huysentruyt et al[36] performed a meta-analysis, including 11 studies comprehending at least one score among *PNRS, STAMP, PYMS,* and *STRONGkids.* Authors concluded that it is not advisable to prefer one single nutritional screening tool because each screening category should be linked to a specific setting. For example, *STRONGkids* may be the best option as a quick tool for testing risk in all age groups, whereas *PYMS* or STAMP may be preferred if anthropometric measures are needed at hospital admission and during the screening process.

Nutritional Global Assessment

After the nutritional risk assessment, necessary for all hospitalized patients, a percentage of patients may result at risk of malnutrition. Hence, a specific nutritional assessment is mandatory, as explained below.

Medical and Dietary History

The checklist in the Table II allows to collect an accurate medical and dietary history, necessary for a global nutritional assessment.

The examination of medical history should include the growth history, the eventual onset of puberty and the psychomotor development with feeding abilities. Previous acute and chronic illness, hospitalization and surgical procedures should be investigated, with emphasis on nutrition-related illness[15].

It is important to establish the duration of the current disease, documenting oral motor skills and swallow ability, GI symptoms, weight changes. The use of certain drugs, which may cause nutritional deficiency, may be documented, as well as the use of any vitamin, mineral or herbal supplement, for their possible interactions with drugs[37].

The detection of dietary history provides information about the child's dietary patterns, the number of meals, food allergies and intolerances, self-imposed and prescribed diets. The dietary food records can be retrospective (usually a 24-hours diet recall) or prospective (usually for three to seven days)[38].

Moreover, food frequency questionnaires give information on the amount and frequency of spe-

Table II. Checklist of medical and dietary history.

Patient's personal and medical history
– Growth history
– Onset of puberty
– Psycomotory development
– Acute or chronic illness
– Hospitalization, surgical procedures
About current disease
– Duration of the current disease
– Oral motor skills, swallow safety
– GI symptoms
– Weight changes
– Use of drugs, vitamin, mineral or herbal supplements
About dietary patterns
– Dietary patterns
– Number of meals
– Food allergies and intolerances
– Self-imposed and prescribed diets
– Food frequency questionnaire (FFQ)

cific dietary patterns, providing an insight into the relation between diet and disease. In their Eating Assessment in Toddlers study, Mills et al[39] demonstrated the validity and the high reproducibility of the Food Frequency Questionnaire (FFQ), for identifying dietary patterns in children.

Physical Examination

The physical examination assesses patient's general conditions and investigates on the presence of signs of specific nutritional deficiencies[15].

In particular, abnormal findings in the examination of hair, eyes, lips and mouth, tongue, teeth, skin, nails usually are related to specific micronutrient deficiency (for example zinc, iron, essential fatty acid, selenium, magnesium, vitamin A, C, B12, folate)[40].

A visual inspection may reveal protein-energy malnutrition in the presence of extremity edema, distended abdomen, muscle wasting. The adequacy of fat stores may be assessed by the inspection and palpation of orbital, triceps, bony, iliac crest prominence and depressions between ribs. Furthermore, the palpation of muscles overlying the clavicle, scapular area, shoulders, quadriceps and calves may allow information about the adequacy of muscle stores: in a well-nourished patient, the muscles appear rounded and well-developed[41,42].

Biochemical Parameters

Laboratory data play a complementary role in the assessment of nutritional status, even if no one lab test can give a comprehensive assessment of nutritional status.

Illness-related malnutrition is often associated with an inflammatory status that promotes a catabolic effect on free fat body mass and muscle protein. The presence of inflammation should be established, because it may decrease the effectiveness of nutritional intervention. Acute phase proteins (C-reactive protein, fibrinogen, haptoglobin, ceruloplasmin, ferritin, and alpha-1-antitripsin) levels are high during an acute inflammation or a catabolic state; conversely, albumin, prealbumin, retinol binding protein (RBP) and transferrin are decreased in these cases[43]. However, the magnitude of a positive acute phase response may be attenuated in "protein energy wasting" (PEW), a process characterized by a first phase of impaired nutrient intake and absorption, followed by a second phase of depletion of body stores, with alteration of biochemical and physiologic functions[44,45].

Anthropometric Measurements

Weight is a measure of overall nutritional status, but it may be influenced by many variables, such as age, sex, daily intakes and hydration status. It is important to remove all excess clothing, measuring weight in light or no clothing and without diaper for infants. Furthermore, the scales should be calibrated monthly, using objects with known weight. Patients older than 2 years of age and able to stand should be weighted on a platform scale with movable weights or with digital scales. Weights are recorded in kilograms and rounded to the nearest 100 grams. For patients unable to stand, bed scales or wheelchair scales may be used as alternative measures. Children under 2 years of age should be weighted placed supine in a pan scale, making sure the weight is scattered equally on each side of the center of the scale. Weights are recorded in kilograms and rounded to the nearest 10 grams[46].

Stature (length, height or alternative height measures) is a very important measure for observing long-term nutritional status. For children under 2 years of age recumbent length is obtained using an infantometer (a solid length board) in the supine position. This measurement requires two individuals: one who holds the child's head straight on the board and a second that extends the child's legs and feet flattened and moves a perpendicular moveable plate against the child's feet. For children older than 2 years of age height is found using a vertical stadiometer, if possible fixed on the wall, with a perpendicular arm moved down to the crown of the head, removing shoes and putting head, shoulders, hells, buttock against the flat surface[46].

For patients with limitations (such as contractures, hip dysplasia, hypertonicity, and inability to

stand) alternative height measures may be found: for details, we suggest *ad hoc* references[47-50].

Head Circumference (HC) may obtained in children until they reach 36 months of age, using a flexible measuring tape placed around the head across the frontal bones, above the eyebrows and the right and left ears, over the occipital prominence at the back of the head. HC should be considered an index of brain development and nutritional status, correlated with undernutrition[51].

Weight for length may be evaluated in patients under 2 years of age to detect a state of overweight or underweight. This calculation corresponds to BMI, used in patients older than 2 years. BMI, also known as "Quetelet's index", is calculated with weight in kilograms divided by height in meters squared [BMI=Weight (kg)/Height^2 (m^2). Given the variability in sex and age, different specific BMI values on growth charts are available in children[15].

BMI has been used to assess obesity since the 1960s in adult[52]; more recently the International BMI cut offs in pediatric overweight and obesity have been developed, based respectively on the adult cut offs of 25 and 30[53,54] kg/m^2.

Despite World Health Organization (WHO) expert committee validated the use of BMI also for assessing thinness in adolescence[55], BMI is not recommended to assess indistinctly underweight or wasting in adolescents or children: in children in fact, underweight is expressed by "low weight for age", whereas wasting is indicated by "low weight for height"[56]. Furthermore, BMI should not be used as the only indicator of nutritional status in children with clinical conditions, because BMI does not consider differences in the composition of the body.

Mid-Upper-Arm Circumference (MUAC), also known as Mid-Arm Circumference (MAC) is a simple measure taken by a flexible tape placed perpendicular to the long axis of the arm, which is flexed at 90° angle. The midpoint of the upper arm halfway between the acromion and the olecranon is measured and marked. Then, with the patient's arm relaxed at the side, the tape is placed around the previously marked midpoint[47]. The MUAC is a better indicator of body composition than BMI in those patients with edema or fluid shifts, because it is not influenced by hydration status. In a study among children at high risk of malnutrition in rural Bangladesh, Roy et al[57] suggested that MUAC may be a potential anthropometric indicator of nutrition in children aged between 6 and 60 months.

Triceps skinfold thickness (TSF) is measured using a skinfold caliper on the right arm at the point marked previously for the MUAC on the back of the arm. The examiner grasps the skin and subcutaneous fat tissue between thumb and forefinger above the point previously marked. After the skin, where the skinfold caliper is placed at the midpoint marked, maintaining a grasp of the skinfold. TSF is commonly adopted for research setting, but it can be also useful for identifying patient's body fat stores.

Once MUAC and TSF are obtained, it is possible to calculate *Mid-Arm-Muscle Circumference (MAMC), Arm Muscle Area (AMA)* and *Arm Fat Area (AFA),* which are useful to distinguish muscle from fat stores. *MAMC* may be calculated from MUAC and TSF using the formula:

$$\text{MAMC (cm)} = \text{MUAC (cm)} - (\text{TSF (cm)} \times \pi)$$

AMA derives from the formula:

$$\text{AMA (cm}^2\text{)} = [\text{MUAC (cm)} - \pi \times \text{TSF (cm)}]^2 / 4\pi.$$

For calculating *AFA,* it is necessary to obtain *Total Arm Area (TAA)* with the formula:

$$\text{TAA (cm}^2\text{)} = \text{MUAC (cm)}^2 / 4\pi$$

Finally, *AFA* derives from the formula[45]:

$$\text{AFA (cm)}^2 = \text{TAA (cm)}^2 - \text{AMA (cm)}^2$$

Handgrip test is a strength measure performed using a handheld dynamometer, which is a non-invasive and low-cost instrument for measuring muscle functional status. Using the dynamometer, the patient performs a sequence of movements that reproduce the maximum strength of the hand and forearm muscles. In adult cohorts it has been evaluated as a sensitive marker of energy intake[58] and bone mineral density[59], while a low handgrip strength is associated with a poor prognosis in cardiovascular and cancer diseases[60,61]. Nutritional changes affect earlier the muscle function than the muscle mass, consequently handgrip strength may help to prompt detect the presence of malnutrition in children. There are some efforts in parameterizing this test[62,63], but appropriate age and gender-specific reference ranges must be used[64].

Percentiles for age and sex traditionally express the position of a child's measurement (weight, length or height, weight for length or BMI) on a bell-shaped standard reference curve, derived from population data.

A percentile indicate the percentage of population that stay above or below that measured in the child, helping to compare the child's position to a population of other children similar for age and sex. However, according to WHO statements, percentiles do not indicate precisely the actual degree of patient's deviation from population standards; conversely, the use of Z scores would be better for expressing anthropometric measures[65]. Z scores are more sensitive than percentiles, because they express in standard deviation (SD) how far from the mean the child is, comparing the individual anthropometric measurement with data from reference age groups. Z scores are available in chart form for several anthropometric measurements (such as weight, height, BMI, head circumference, MUAC, TSFT). Online calculators such as "*Peditools.org*" are actually available for automatically calculating Z scores.

In their study Green Corkins et al[41] derived the degree of malnutrition from the Z score of weight for height, BMI for age, MUAC: -1 to -1.9 Z scores assess mild malnutrition, -2 to -2.9 Z scores assess moderate malnutrition, below -3 Z scores assess severe malnutrition (Table III).

Growth charts collect the patient's anthropometric measurements, allowing an assessment of the growth over time and facilitating clinicians in an early identification of a faltering growth[66]. It is recommended to use the 2006 WHO charts as normative standards for term infants and children up to 2 years of age and the 2000 Center for Disease Control and Prevention (CDC) charts for children and adolescents from 2 to 20 years of age. These charts are available for both female and male, allowing the assessment of percentiles and Z score for several anthropometric measurements (weight for age, height or length for age, head circumference for age, BMI for age)[67,68].

Furthermore, several growth charts are currently available for different disease and syndromes (such as prematurity, Down syndrome, Turner syndrome, Prader-Willi syndrome, Noonan syndrome, achondroplasia, cerebral palsy, Duchenne muscular dystrophy)[69].

Indicators of the Body Composition

Body composition measurements can predict clinical outcomes and nutritional status in children and adolescent. Body composition measurements are really demanding in children and adolescents, because of the growth-related changes in height, weight, fat-free mass (FFM), total body water (TBW) and total extracellular tissue.

Numerous techniques exist for routine determination of body composition, including total body potassium counting (TBK), dual-energy X-ray absorptiometry (DXA), single and multifrequency bioelectrical impedance analysis (BIA). Although these reference methods are used routinely, each one has intrinsic practical limitations[70].

The detection of nutritional status in children with clinical conditions requires the measurement of both fat mass (FM) and fat free mass (FFM). Body cell mass (BCM) is the metabolically active component of FFM and expresses the functional cellular component of the body. BCM may be an ideal indicator of nutritional status in children with clinical condition, because it is independent of hydration changes that occur with disease. BCM is calculated from total body potassium counting (TBK), using the formula of Wang et al[71]:

$$BCM\ (kg): (TBK\ (g) \times 9.18) / 39.1$$

Murphy et al[72,73] demonstrated that BCM measurement by TBK might be a valid indicator of nutritional status in children with cancer, because it is independent of extracellular fluid changes produced by the disease. However, TBK measurements may not be widely available, so alternative simple methods such as DXA and BIA can provide measures on FM and FFM[74].

Dual-energy X-ray Absorptiometry (DXA) is a noninvasive method that can be applied at all ages for the measure of regional body composition. DXA may allow the determination of three main body components (bone mineral, bone-free FFM, and fat mass) with low-radiation exposure, short scanning time and low cost[75]. DXA is accepted for the analysis of body composition and for the measure of adipose tissue mass in pediatric population[76].

Table III. Z scores ranges in nutritional assessment.

	Mild malnutrition	Moderate malnutrition	Severe Malnutrition
Weight for height Z score	-1 to -1.9	-2 to -2.9	-3 or greater
BMI for age Z score	-1 to -1.9	-2 to -2.9	-3 or greater
MUAC Z score	-1 to -1.9	-2 to -2.9	-3 or greater

§adapted from Green Corkins K.et al[41]
BMI: Body Mass Index; MUAC: Mid-Upper Arm Circumference

Bioelectrical impedance analysis (BIA) is another safe, non-invasive and manageable method generally used for the indirect determination of body composition[77]. BIA method is based on the principle that the conduction of an alternate electric current in a body may find a resistance to the passage (impedance) inversely proportional to the contents of water and electrolytes. In this concept, legs and arms are theoretically comparable to cylindrical conductors in which FFM (made of well hydrated cells) offers a relative slow impedance, while FM (poor in water and electrolytes) opposes an high impedance. The bones, air (in the lungs) and parenchymal organs are not considered good conductors and are not taken into account. The impedance (Z) at the passage of current trough the body consists of two components: resistance (R) and reactance (Xc). R depends essentially on the extracellular water (ECW) and FM. Xc is an indirect measure of body cell mass: it is the quality of healthy cell membranes of taking an electric load and liberate it in a second moment, after a brief delay. This is a capacitance-like property, similar to that of vessels or condensers in electrical circuits. There are two kind of measure in BIA methods: the single frequence (SF-BIA) and the multi-frequencies (MF-BIA). At single frequency (often 50 kHz), Z is given principally by R, since the only resistance is offered by ECW. In MF-BIA, current could pass at higher frequencies (100-200 kHz), recruiting during the passage many functioning cells, whose contents (water and electrolytes) enhance its conduction: the results is a lower resistance and a higher reactance (Figure 1).

SF-BIA is commonly used to estimate total body water (TBW) and fat free mass (FFM), conversely MF-BIA allows the advantage of a differentiation between intracellular and extracellular TBW. Nevertheless, SF-BIA is more validated in children, because only recently MF-BIA devices have been marketable[78].

Tyrrel at al[79] demonstrated that BIA performs better than anthropometric indices in the estimation of fat-free mass (FFM), fat mass (FM) and percentage body fat (PBF) in children.

BIA measures total water content of body (TBW) not directly, but through prediction equations for calculating total body water (TBW) and FFM as a function of impedance, weight, height, sex and age. BIA equations to estimate TBW, FFM or FM are based on adult proportions and they may be less accurate in children, because the hydration fraction changes during childhood and adolescence. Consequently, pre and post pubertal age, gender, ethnic differences and changes in hydration must be take into consideration, when validating separate BIA equations for children[80,81].

The use of Phase angle (PhA) is remarkable in a clinical setting, it reflects body cell mass (BCM), and it is also one of the best indicators of cell membrane function[82]. PhA is a derived measure of BIA method, calculated from R and Xc with the following formula:

$$PhA = \arctan (Xc/R) \times (180/\pi)$$

PA is an indirect measure but it is proportional to body cell mass and its value depends on tissue health and age. In healthy adults the mean value is around 5.6, with lower values in females and older subjects [83-85]. It has been recognized as a measure of

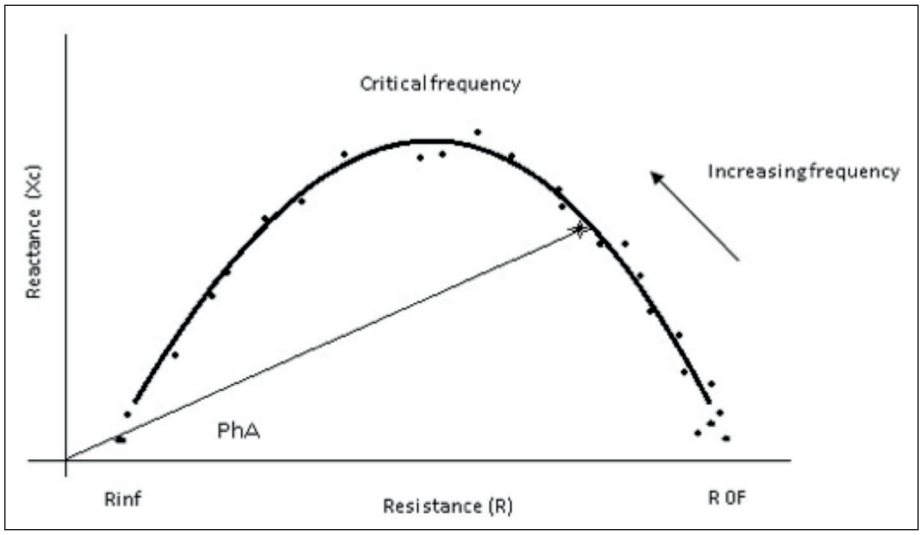

Figure 1. Relationship between Resistance (R) and Reactance (Xc): at increasing frequencies, Xc increases, R decreases. Rinf: Resistance at infinite frequency; R 0F: Resistance at zero frequency; PhA: Phase Angle. Modified from ESPEN textbook: Basics in clinical nutrition, fourth edition[78].

nutritional status both in adults and in hospitalized children[58,86] and a prognostic factor of survival in adults affected by cancer[87-89]. Farias et al[90] showed that PhA may be a prognostic and nutritional status indicator for children and adolescents undergoing hematopoietic stem cell transplantation (HSCT). On the same way, Pileggi et al[91] demonstrated that PhA may be a good and sensitive method for identifying nutritional risk at hospital admission and monitoring nutritional status of children during hospitalization. In this cross-sectional study, PhA in children was around 5 in healthy control subjects (with some difference due to age and sex) with significantly lower values in hospitalized patient. Actually, PhA is strongly recommended by ESPEN as a prognostic nutritional measure[92].

Edefonti et al [93,94] assessed the prevalence of malnutrition in children on chronic peritoneal dialysis, using the anthropometry-biompedance analysis nutrition (ABN) score. This score uses six parameters based on anthropometry BIA values. The sum of each score gives a result ranging from 10.33 to 15.00 in healthy children, and below 10.33 in malnourished children. This method appears to be non-invasive, reliable, and easy to measure both in ill and healthy children. Moreover, it was used in a special cohort of patient, affected by protein energy malnutrition. In the future, several studies may be necessary to validate this method in other similar clinical context.

Conclusions

Hospitalized children should be firstly assessed for nutritional risk. In this setting no a defined tool is suitable for every situation, even if STRONGkids score appear to be the most quick, reliable and practical to use since from the admission in the hospital. When a high risk of malnutrition is found in a hospitalized child or adolescent, a nutritional global assessment must be performed by a pediatrician or a clinical nutritionist. For this purpose, medical and dietary history, physical examination and anthropometric measurements are well accepted and validated methods. Among body composition analysis procedures, BIA represents a non-invasive, safe and easily performed tool with an increasing number of supporting studies. Given the availability of so many resources in modern clinical settings, every effort should be carried out to early identify and promptly correct malnutrition among hospitalized children.

Conflict of interest

The Authors declare that they have no conflict of interests.

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