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Evidence on nutritional assessment techniques and parameters used to determine the nutritional status of children and adolescents: systematic review

Evidência sobre técnicas e parâmetros de avaliação nutricional para crianças e adolescentes: revisão sistemática

Aline dos Santos Sampaio [1]
Matias Epifanio [1]
Caroline Abud Drumond Costa [1]
Vera Lúcia Bosa [2]
Franceliane Jobim Benedetti [3]
Edgar Enrique Sarria [4]
Suelen Goecks Oliveira [1]
Eduardo Mundstock [1]
Rita Mattiello [1]

Abstract *This article aims to review systematically the evidence on nutritional assessment techniques and parameters used to determine the nutritional status of children and adolescents. The literature review and the selection of publications were performed using the Medline, Lilacs, SciELO, Embase, personal files. 17 studies were identified, 7 addressed the anthropometric indices as the main outcome, 7 analyzed the growth and development of children and adolescents through growth curves, and the remainder surveyed body composition. In general, all met the quality criteria, unless 6 of the articles who did not discuss the limitations. The literature review suggests several techniques and parameters that can be applied to determine the nutritional status of children and adolescents from different countries. Growth graphs are essential to assess the health of children, but depend greatly of the growth tables used. Although BMI can be practical, it does not distinguish body fat from lean mass. The best interpretation of anthropometry will depend of valid reference values for age range of the study population. BIA is a quick feasible method, but the measurement has some various nationalities.*

Key words *Nutritional status, Children, Body composition*

Resumo *O objetivo deste artigo é revisar sistematicamente as evidências sobre as técnicas de avaliação nutricional e parâmetros utilizados para determinar o estado nutricional em crianças e adolescentes. Revisão da literatura com busca nas bases de dados, Medline, Lilacs, SciELO e Embase, além de arquivos pessoais. Identificamos 17 artigos que relatavam dados de diferentes populações, sete estudos abordaram os índices antropométricos, quatro o crescimento e o desenvolvimento de crianças e adolescentes por meio de curvas de crescimento, e o restante a composição corporal. Todos preencheram os critérios de qualidade, com exceção das limitações. A revisão da literatura sugere diversas técnicas e parâmetros que podem ser aplicados para determinar o estado nutricional de crianças e adolescentes de diferentes países. Gráficos de crescimento são essenciais para avaliar a saúde de crianças, mas depende muito das tabelas de crescimento utilizadas. Embora o IMC seja prático, não distingue a gordura corporal de massa magra. Existem várias técnicas para avaliar proporções, tamanho e composição corporal. A melhor interpretação da antropometria dependerá de valores de referência válidos para a faixa etária da população estudada. BIA é um método factível, mas tem algumas limitações para a realização do exame.*

Palavras-chave *Estado nutricional, Crianças, Composição corporal*

[1] Programa de Pós-Graduação em Pediatria e Saúde da Criança, Pontifícia Universidade Católica do Rio Grande do Sul. Av. Ipiranga 6690/2º, Partenon. 90610-000 Porto Alegre RS Brasil. rita.mattiello@pucrs.br
[2] Programa de Pós-Graduação em Alimentação, Nutrição e Saúde, Universidade Federal Federal do Rio Grande do Sul. Porto Alegre RS Brasil.
[3] Universidade Franciscana. Santa Maria RS Brasil.
[4] Hospital Santa Cruz, Universidade de Santa Cruz do Sul. Santa Cruz do Sul RS Brasil.

Introduction

The assessment of nutritional status is an indicator of health and well-being, both at the individual and population level[1]. It is important to define situations of risk when planning health promotion actions, nutritional diagnosis and prevention of diseases[2]. It is essential to perform a systematic follow up of development and growth, since it monitors and favors health and nutrition conditions of children and adolescents[3].

Currently excess weight in children and adolescents is a relevant and frequent situation worldwide[4,5]. Diagnosis of excess weight requires the identification of levels of risk that often make it necessary to use appropriate techniques[6].

There are different techniques and instruments to assess the nutritional status of children and adolescents, which makes it difficult to choose the criterion and interpret the results used by health care professionals[7]. In order to be clinically important, the nutritional assessment methods must be accurate, precise, specific regarding the nutritional status and sensitive to their changes, besides being easy to apply and reproduce[8]. Anthropometry has been considered the most appropriate parameter to assess collective nutritional status[9], especially in childhood and adolescence, because it is easy to perform, with a low cost and innocuous[10].

When selecting the nutritional assessment technique, one must choose the one that meets the objective, considering the cost of its use, level of personal skill required to apply it appropriately, and also time needed to implement it, how it is received by the population studied and possible health risks[11,12].

Several countries use international recommendations and parameters to assess the nutritional status of children and adolescents. However, there are questions about these recommendations and parameters, particularly concerning their validity, since many of them do not use samples representing several countries, and may express a local reality, and their use is generalized to the population at large. Thus, this review systematically seeks evidence on the forms of nutritional assessment and the parameters used to determine the nutritional status of children and adolescents, summarizing the instruments available for this purpose.

Methods

The systematic review followed MOOSE guidelines[13] and is registered in the PROSPERO database.

Search strategy and selection criteria

We searched the following databases: Medline, Embase, Lilacs, from inception to April 2014. We have also searched the grey literature, discussed the subject with leading experts in the field, and searched reference lists of other recent systematic reviews.No filters were selected for electronic searches. The search was performed using the following combination of terms:AnthropometryOR "Body composition" AND "Nutrition Assessment".

Eligibility criteria

All original articles that covered a development or validation of nutritional assessment technique and/or parameters used to determine the nutritional status of healthy children and adolescents aged 0 to 19 years were included in this review. We exclude the following types of article: Letters to the editor, case reports and comments; studies involving special groups such as children and adolescents with pathologies or in hospital; systematic review articles and studies without a complete text.

Data extraction

From each of the selected studies, the following variable data was extracted: first author's name, age, assessment method, outcome, method validation, validation of the method, results obtained and observations.

Selection of articles

Two reviewers, working independently, screened all titles and abstracts to identify studies that could meet inclusion criteria, or that could not be safely excluded without assessing its full text. Initially, titles and abstracts were analyzed in an independent way and, subsequently, studies were selected for full text reading according to eligibility criteria previously established. Divergences were solved by consensus and when still discordant, a third reviewer served as a judge.

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Analysis of risk of bias

The quality criteria used to evaluate the studies selected are shown were elaborated using two references mentioned in the *Guidelines for Systematic reviews of health promotion and public health interventions*: *Critical Appraisal Skills Programme* (2013) and *McInnes* and *Chambers* (2008)[14,15]. With the combination of these two methods we elaborate our assessment tool the quality of the selected studies. With this we will evaluate the following items in each article: 1) Is the nutritional assessment method used clear? 2) Were values of reference or nutritional assessment methods created and/or validated? 3) Are the participants appropriate for the research question? 4) Were the nutritional assessment methods used described adequately? 5) Are the variables collected in accordance with the nutritional assessment methods chosen? 6) Were the results presented in an organized, logical manner, appropriate to the type of study? 7) Is the survey internally and externally valid? 8) Are the study limitations discussed? 9) Are the study conclusions correct? In each item two authors, independently, pointed out yes; No or not applicable (Table 1).

Table 1. Quality criteria.

Questions	Options for answers		
1. Is the nutritional assessment method used clear?	Yes	No	Not applicable
2. Were values of reference or nutritional assessment methods created and/or validated?	Yes	No	Not applicable
3. Are the participants appropriate for the research question?	Yes	No	Not applicable
4. Were the nutritional assessment methods used described adequately?	Yes	No	Not applicable
5. Are the variables collected in accordance with the nutritional assessment methods chosen?	Yes	No	Not applicable
6. Were the results presented in an organized, logical manner, appropriate to the type of study?	Yes	No	Not applicable
7. Is the survey internally and externally valid?	Yes	No	Not applicable
8. Are the study limitations discussed?	Yes	No	Not applicable
9. Are the study conclusions correct?	Yes	No	Not applicable

Results

Table 1 displays the flow diagram of our search strategy and study selection used on our systematic review. Using this approach, we found 3.737 articles in three different databases and grey literature. After excluding 5 duplicated studies, 3.732 studies were selected for further abstract reading. Among these, we excluded 3709 articles who did not meet our inclusion criteria.

Seventeen relevant articles were identified that supply data on different populations, Venezuelans, Africans, and others. Seven studies discussed the anthropometric indices as the main outcome, four analyzed the growth and development of children and adolescents using growth curves, and the remainder of the studies looked at body composition. The articles selected were published from 1974 to 2014, the age group of the participants ranged from birth to 19 years of age. Tables 2, 3, S1 and S2 summarized the articles included in this review.

Concerning the evaluation of the methodological quality of the articles, all of them generally attained the quality criteria. Except for the question on limitations, six of the 17 articles included did not discuss their limitations. Hence, none of the studies presented all the quality requirements. However, it is justified to include all of them, since they can help understand the nutritional assessment techniques for the population of children and youths.

Table 2 shows the studies performed on predominantly American individuals, aged from birth to 19 years. The surveys were published between 1977 and 2007. Since this was recommended internationally, some of the surveys involving BMI for age were performed on children and adolescents. According to the data shown in Table 3 three studies using BMI for age were performed in Brazil. These surveys included children and adolescents aged two to 19 years, and newborns with a gestational age of 29 to 43 weeks. The studies presented different objectives and outcomes.

Table S1 presents five studies that used anthropometric measures to determine the nutritional status in American and African individual

Table 2. Anthropometric assessment: Growth curves.

Author, year	Assesment measure	Population	Age	Sample Size	Sex	Year	Indicatorns/Indices	S	Spec
NCHS, 1977[17]	Anthropometry	American	Birth – 18 years		M,F	1929 - 75 1960 - 75	Curves; WA; WH; HA; CCA	No	No
CDC, 2000[19]	Anthropometry	American	Birth – 20 years		M,F	1963 – 65 1966 – 70 1971 – 74 1976 – 80 1988 - 94	Curves; BMIA; CCA; LA; WS; WA	No	No
WHO, 2006[20]	Anthropometry	USA; Ghana; India; Norway; Oman; Brazil.	Longitudinal: birth - 24 months. Cross-sectional: 18 - 71 months	8,440	M,F	1997 - 2003	Curves; WA; WH; WS; BMIA	No	No
WHO, 2007[21]	Anthropometry	American	5 – 19 years	22, 917	M,F	New analysis of the NCHS data for 1977	Curves (5-10 years): WA, LA, BMIA. Curves (10-19 years): LA, BMIA.	No	No

Legend: NCHS (National Center for Health Statistics). WHO (World Health Organization). M (Male). F (Female). S (Sensitivity).Spec (Specificity). WA (Weight for age). WH (Weight for height). WS (Weight for stature), LA (Length/Stature for age). BMIA (BMI for age). WH (Weight for height). HA (Height for Age). CCI (Cephalic Circumference for age).

at ages between birth and 74 years. Table S2 presents two studies that used BIA to determine body composition in English and Danish children and adolescents aged three to 18 years.

Discussion

Growth graphs are essential to assess the health of children and adolescents, but following the growth trajectory and, consequently, the decision to intervene, depend greatly of the growth tables used[16]. In the last 50 years, many authors from several countries produced different frames of reference to assess the nutritional status[17].

In 1977, the National Center for Health Statistics (NCHS) and the United States Center for Disease Control (CDC), developed growth curves by grouping the longitudinal data on children (0-23 months) and cross-sectional data collected respectively by the Ohio Fels Research Institute and by the National Health and Nutrition Examination Surveys (NHANES)[18].

A few inconsistencies observed in the NCHS/WHO growth reference, especially regarding breastfeeding, led the people who studied it to conclude that new references would be needed[19]. In 2000, the Center for Diseases Control (CDC) launched a new set of tables and growth graphs. These curves were elaborated using the data from the previous curves of the NCHS in 1977, with a few modifications in the sample of children[20].

In 2006, the World Health Organization (WHO) established a new international standard by elaborating a set of curves to assess the growth and nutritional status of children up to the age of five years[21]. The position of WHO is that all economically disadvantaged children who were breastfed when babies, grow similarly, and consequently, a single set of growth graphs can be used to evaluate the growth of any child, independent of race or ethnicity[22].

The 2006 frame of reference was produced based on a sample from six countries. Curves were developed with Z-score and percentiles: Weight for age, Weight for length (up to two years), Weight for stature (two to 5 years), Length/Stature for age and BMI for age[21]. At the WHO site, the tables and graphs (http://www.who.int/childgrowth/standards/en/) are available for free access.

The WHO 2006 frame of reference presents advantages over the previously recommended CDC/NCHS (2000), since it provides references for more anthropometric parameters, besides

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Table 3. Anthropometric indices

Author and year	Assessment measure	Population	Age	Sample size	Sex	Year	Indicators and Índices	S	Spec
Abrantes *et al*, 2003.[25]	BMI for age	Brazilian	2-10 years	2,920	M, F	Cole *et al*, 2000. Must *et al*, 1991.	-	90%	100%
Wolney Conde *et al* 2006.[23]	BMI for age	Brazilian	2-19 years	26,102	M, F	PNSN of 1989	Critical values of BMI for low weight, excess weight and obesity.	No	No
Brock RS *et al*, 2008.[24]	BMI for age, newborns	Brazilian	GA 29 to 42 weeks	2,406	M, F	1993-04	Percentile BMI for GA	No	No
Duncan Scott *et al*, 2009.[53]	BMI for age	European, Pacific Islands, Maori, Eastern Asia, South Asia	5-16 years	1,676	F	-	-	90-92,3%	66,7-80,3%
Rached-Paoli*et al*, 2010.[30]	BMI for age, pregnant women	Venezuelan	12-18 years	367	F	1999-08	-	87,3%	94,8%
Foo LH *et al.*, 2013.[29]	BMI, WC, WHR, WHR1, TBF, % BF, AF, TF.	Asian	12-19 years	454	M, F	2013	-	No	No
Griffiths C *et al.*, 2013.[33]	BMI, WC	British	11-16 years	746	M, F	2005-10	-	No	No

Legend BMI (Body Mass Index) BMIA (Body Mass Índex for Age). GA (Gestational Age). DEXA (Double Energy X-Ray Absorptiometry). WC (Waist Circumference). WHR (Waste Height Ratio). WHR 1 (Waist Height Ratio).TBF (Total Body Fat). % BF (% Body Fat Percentage). AF (Fat Androide). TF (Fat Trunk). M (Male). F (Female). S (Sensitivity) Spec (Specificity).

having a frame of reference for body mass index for children below the age of two years, which does not exist in CDC/NCHS 2000. Consequently, the WHO frame of reference for 2006 began to be adopted in the health care services, and the need arose to provide an adequate complementary reference continuing that of 2006, for children over the age of five years[17].

Thus, in 2007, the growth curves were launched by the World Health Organization and a new analysis of the data from the *National Center for Health Statistics* (NCHS) of 1977 was performed. The 1977 data were merged with the data used in the WHO curves of 2006, for children under the age of five years[23]. This set of data covers the Weight for age and sex curves (from five to 9 years of age); Stature for age and sex (from five to 19 years); and BMI for age and sex (from five to 19 years). The tables and graphs supplied on internet allow the use of the reference in practice (http://www.who.int/growthref/en/).

All the articles included in this review of growth curves created values of reference for the child and adolescent population of different nationalities. According to the data presented in table 2, it can be perceived that the recommendations and growth curves were constantly modified and analyzed again for a better identification of the nutritional status. Both the WHO curves of 2006 and 2007 that were launched for the children over five years of age, are indicated and used internationally for the nutritional diagnosis of children and adolescents.

The word index refers to the combination between two anthropometric measures. The anthropometric indices enable a more complex and detailed assessment of the nutritional status. The body mass index (BMI) for age is most used, and it is internationally recommended in the individual and collective diagnosis of nutritional disorders. This index expresses the relationship between weight and the square of stature, and it is used mainly to identify excess weight[17].

Conde and Monteiro, recommend using a new BMI graph for children and adolescents in clinical and epidemiological assessments. The classification system generated in this survey was methodologically similar to most of the national curves and also presents the definition of low weight[24]. Similarly, Brock et al., presented percentile curves of BMI for newborns of different gestational ages. The results demonstrated a direct correlation between BMI and gestational age in all percentiles analyzed, and these findings can provide a useful tool to determine normal intrauterine growth[25].

On the other hand, Abrantes et al. considered the weight index for height as the gold-standard in relation to the BMI cutoff points for overweight and obesity proposed by Cole et al. and Must et al. The sensitivity and specificity found were high. Although the values proposed by both are similar, the researchers suggest using the values of Cole et al. and emphasize that the values proposed by both must be carefully used to screen for obesity in childhood, but can be used to diagnose children with excess weight[26].

Other similar studies were conducted with children and adolescents of different nationalities aged from five to 19 years of different nationalities.

Duncan et al.[27] suggest that BMI may be an acceptable substitute measure to predict the excess of fat in girls of different ethnicities. Similarly, in a recent study, the researchers determined the usefulness of several anthropometric measures to establish regional and total body fat, using Double Energy Xray Absorptiometry (DEXA) as a gold standard. The results confirmed that an anthropometric index like BMI can be an substitute indicator to estimate body fat in Malay and Chinese adolescents[28].

Paoli et al. analyzed the capacity of four reference values based on BMI to categorize the nutritional status of pregnant adolescents. The researchers suggest the use of the Frisancho reference to diagnose the nutritional status in the first trimester of pregnancy in adolescents and populations with similar characteristics[29,30].

According to the studies presented, the researchers indicate that BMI may be a substitute measure to predict excess fat, since it is highly sensitive and has great specificity compared to the weight-for-height index, and it is recommended to use a new BMI graph for children and adolescents in clinical and epidemiological assessments. As to the newborns, the BMI has a direct correlation with gestational age and new percentile curves are presented for pregnant women, and the use of the reference of Frisancho (1993) is recommended.

Although BMI can be sensitive and specific to predict body fat, a great number of children and adolescents classified as overweight or obese do not have high body fat, since BMI does not distinguish body fat from lean mass, making it difficult to differentiate overweight with excess fat from overweight with muscle hypertrophy[31].

In a recent study the researchers looked at the prevalence of obesity over five years in the same individuals, comparing the body mass in-

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dex, waist circumference and waist-stature ratio. It was found that central adiposity measured by waist circumference is increasing together with the stabilization of BMI, ie., additional adiposity is being stored centrally, and not detected by BMI[32].

In addition, although BMI does not represent the body composition of individuals, its use in epidemiological studies and in clinical practice is justified because it is easy to obtain data on weight and stature, as long as the cutoff points used are age specific, especially if associated with other anthropometric measures that express the composition and distribution of body fat[33].

In Table 3, Brazilian newborns, children and adolescents were included in three surveys in which the researchers recommend the use of a new BMI graph in clinical and epidemiological assessments. They suggest that BMI is highly sensitive and specific compared to the weight-for-height index and present percentile curves for BMI for newborns at different gestational ages. Even if this index has limitations, it is currently the favorite to determine excess weight in children and adolescents, besides not being invasive and being universally applicable to assess the nutritional status.

Currently the study of body composition is improving due to the various applicability and also because it has been understood that use of body measures alone does not allow a detailed assessment of the growth and nutritional status of children and adolescents[34]. There are several techniques to assess proportions, size and body composition, among them anthropometry, which includes besides measurements of weight and height, skin folds and circumferences. The best interpretation will depend of valid reference values for age range of the study population.

Frisancho (1974) supplied percentiles by sex and age of the triceps skin fold and circumference, muscle area and diameter of the arm for Americans aged 0 to 44 years. According to the researcher, the applicability of data derived from this survey depends on the population that is to be studied, since there are variations in the amount of subcutaneous fat and also in the fat deposition pattern that must be taken into account when assessing the nutritional status[35].

The sample included in 1974 weighted for the low income groups and did not constitute a sample of the national population. Besides, the study did not supply information for individuals over the age of 44 years; for this reason, it had limited applicability to the elderly. Thus, Frisancho (1981) derived new standards from the set of data of the *Epidemiological and Nutrition Examination Study I* (HANES I) from the United States[36]. Later, other percentile tables proposed by Frisancho (1990) were launched, and are currently used.

According to the surveys described, complementary measures to assess the nutritional status of children and adolescents can be performed using assessments of the arm circumference, which represents the sum of the areas formed by the tissues. The muscle circumference of the arm is considered a good indicator of the reserve of muscle tissue, and skin fold which is a measure of adiposity that allows evaluating body composition[35,37].

The folds are correlated differently with total body fat and percentage of body fat according to where they are measured[38]. The most used for this purpose, in children and adolescents, are the triceps e subscapular skinfolds[17]. The triceps skinfold is more valid and presents a better correlation with the percentage of body fat, and is a good indicator of energy reserve[38].

The precision of the data derived from the skinfolds can be highly variable and depends on the operator. Therefore, it requires long training to obtain precise and accurate results. A major limitation of the use of the skinfold method is the difficulty of standardizing the assessors regarding the anatomical points and procedures adopted to perform the assessment[39].

Besides the triceps and subscapular skin folds, arm circumference may be useful to determine body composition more precisely. The arm circumference is used worldwide, and was proposed as an alternative to assess nutritional status in places where it is not easy to collect weight and stature[19].

Ball et al. (1993) determined the sensitivity and specificity of the arm circumference/cephalic perimeter ratio in a group of African children. The arm circumference was more sensitive for screening protein-energy malnutrition than the arm circumference/cephalic perimeter ratio. Thus, the addition of measurements of the cephalic perimeter is not justified by the findings of this survey[40].

Using the arm circumference and arm circumference obtained with the Z score, Rasmussen et al. (2012) assessed which of these variables was best to identify children at high risk of mortality. The findings suggest that both have the same prognostic capacity of short term prediction of mortality. Thus, the researcher indicate that there is no need to use the Z score arm circumference to identify children at high risk of mortality, since the arm circumference is easier to use in the field[41].

Therefore, arm circumference can be used as a complement to other anthropometric measures, or alone, when it is not easy to obtain weight and stature. It is a sensitive method to screen for protein-energy malnutrition, and has a prognostic capacity of predicting mortality over the short term. As to the studies included (table S1), it can be noted that there is an evolution in the recommendation and use of anthropometric measures.

Currently there are many techniques to evaluate body composition that are based on different principles and body models which allow characterizing the body composition in a specific form, distinguishing the different body compartments, or in a comprehensive, non-differentiated form[42,43]. The doubly indirect techniques are less rigorous, but present a better practical application and lower financial cost, and can be used both in field surveys and in clinical studies. Outstanding among them is electrical bioimpedance (BIA)[42].

BIA is a quick method, portable, painless and relatively precise, which consists of passing a high frequency and low amplitude electrical current[44]. Measurement is based on the fact that the free mass of fat contains electrolytes and acts as a conductor, while body fat is relative free of ions and acts as an insulator[45]. The apparatuses available for this assessment supply fat mass, lean mass and body water values, using equations adjusted for sex, age, weight, height and level of physical activity. However, the predictive equations vary according to the apparatus and are valid only for the population of that origin, requiring cross-validation in other population groups[46]. Besides that, BIA measurement has some limitations, such as fasting for several hours before the exam, supposedly to have more accurate measurement; this time restriction limits the use of BIA in large scale studies and even in clinical settings.

Although it is technically easy and highly reproducible, the standardization of the conditions to measure electrical bioimpedance is essential to obtain exact, precise and reproducible data. Several individual and environmental factors can influence the analysis of BIA, such as alcohol ingestion, intense physical activity performed before the test, situations with abnormal hydration of the tissues, as in edemas, ascitis or altered ionic balance[47,48].

A study published in 2006 showed percentile curves for body fat measured by the BIA. The participants were 1985 children aged from five to 18 years. According to the researchers, the curves developed reflect the known differences in adiposity between boys and girls. This set of data was published by the Child Growth Foundation for clinical monitoring of body fat, together with the software to convert individual measures into Z-scores[49].

A recent survey of 99 Danish children developed prediction equations to estimate the fat free mass. BIA and Double Energy X-ray Absorptiometry (DEXA) were used to assess body composition. According to the researchers, the equations developed are particularly relevant for use among healthy Caucasian children aged 2 to 4 years, and can be useful for population studies that connect early risk factors to body composition and the early onset of obesity[50].

BIA can be used to assess body composition of children and adolescents, substituting the skin folds, because this method eliminates inter and intra examiner errors, and does not require trained technicians to be implemented. However, when BIA is used to assess body composition, it is essential to avoid conditions that might create biases as much as possible[51].

Both BIA and anthropometric measures are considered simple, accurate procedures to determine the nutritional status of children and adolescents. Attention must be paid to the conditions that may determine biases in measurement in order not to compromise data reproducibility.

Conclusion

The literature review suggests several techniques and parameters that can be applied to determine the nutritional status of children and adolescents from different countries.

Growth graphs are essential to assess the health of children and adolescents, but, the decision to intervene, depend greatly of the growth tables used.

Although BMI can be practical to predict body fat, but it does not distinguish body fat from lean mass. There are several techniques to assess proportions, size and body composition, among them anthropometry. The best interpretation will depend of valid reference values for age range of the study population.

Currently there are many techniques to evaluate body composition. BIA is a quick method, portable, painless and relatively precise, but the measurement has has some limitations, such as

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fasting for several hours before the exam, supposedly to have more accurate measurement; this time restriction limits the use of BIA in large scale studies and even in clinical settings.

Although a few of the parameters are internationally recommended, there is a need for further studies to validate and create reference values that cover children and adolescents of various nationalities.

Collaborations

R Mattiello and AS Sampaio: introduction, methodology, discussion and final writing. M Epifanio, CAD Costa, VL Bosa, FJ Benedetti, EE Sarria, SG Oliveira: methodology and final writing. E Mundstock: discussion, final writing and formatting text, tables and figures.

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