REVIEW ARTICLE

INTERNATIONAL JOURNAL OF KINANTHROPOMETRY

DOI: 10.34256/ijk26111

Protocol for Anthropometric and Body Composition Assessment in Child Undernutrition: A Review and Consensus Document of The International Society for the Advancement of Kinanthropometry (ISAK)

Lorenzo Alejandro Landa Pérez [1, 2], María Dolores Cabañas Armesilla [3], Adán Israel Rodríguez-Hernández [4], Ka Yiu Lee [5], Irina Livier Rangel-García [6], Claudia Maceroni [7, *]

[1] Centro de Asesoría y Valoración del Estado Físico (CAVEF), México
[2] Secretaría de Educación de Veracruz, México
[3] Universidad Complutense de Madrid, España
[4] Universidad Autónoma de Aguascalientes, México
[5] Oxford Brookes University, United Kingdom
[6] Instituto Tecnológico y de Estudios Superiores de Occidente (ITESO), México
[7] Sports Science Research, USA
* Corresponding author email: claudia@threebalance.com
DOI: https://doi.org/10.34256/ijk26111
Received: 05-01-2026; Revised: 30-03-2026; Accepted: 08-04-2026; Published: 20-04-2026

Abstract

Introduction: Child undernutrition is becoming a physical and mental health problem worldwide as well as an economic development one. It is characterized by wasting (low body mass for stretch stature), stunting (low stretch stature for age) or being underweight (low body mass for age), and reflects nutritional deficiencies in growth and development at critical stages of life. In accordance with the United Nations initiative to reduce malnutrition by 2030, diagnosis, treatment or prevention of any type of child malnutrition is necessary. The objective of this review and consensus document is to offer a standardized frame of measurements and adaptations to the protocol used by the International Society for the Advancement of Kinanthropometry (ISAK) to evaluate undernourished children. **Methods:** A systematic literature review was conducted using the PRISMA guidelines to identify the existence of different anthropometric measurements and methods to evaluate undernourished children. There are important differences in severe acute or chronic child malnutrition clinical conditions which require a different anthropometric approach. Additionally, the distinct growth and development stages of a lifespan require the adaptation of materials and methods used. Other ethical and practical recommendations are included as necessary in the evaluation of undernourished children. **Results:** Finally, estimation of body composition in this population must be approached with caution since clinical conditions do not always allow for the necessary measurements. **Conclusion:** This review can serve as a practical clinical guideline to conduct anthropometric measurements in child undernutrition.

Keywords: ISAK, Children, Undernutrition, Body Composition.

Resumen

Introducción: La desnutrición infantil se está convirtiendo en un problema de salud física y mental a nivel mundial, así como en un obstáculo para el desarrollo económico. Se caracteriza por la emaciación (baja masa corporal para la estatura), el retraso en el crecimiento (baja estatura para la edad) o el bajo peso (baja masa corporal para la edad), y refleja deficiencias nutricionales en el crecimiento y desarrollo durante etapas críticas de la vida. En consonancia con la iniciativa de las Naciones Unidas para reducir la desnutrición para el año 2030, resulta indispensable el diagnóstico, tratamiento o prevención de cualquier tipo de desnutrición infantil. El objetivo de este documento de revisión y consenso es ofrecer un marco estandarizado de mediciones y adaptaciones al protocolo utilizado por la Sociedad Internacional para el Avance de la Cineantropometría (ISAK) para la evaluación de niños desnutridos. **Métodos:** Se llevó a cabo una revisión sistemática de la literatura, siguiendo las directrices PRISMA, con el fin de identificar la existencia de diferentes mediciones y métodos antropométricos para evaluar a niños desnutridos. Existen diferencias significativas en las condiciones clínicas de la desnutrición infantil, tanto aguda grave como crónica, las cuales exigen un enfoque antropométrico diferenciado. Asimismo, las distintas etapas de crecimiento y desarrollo a lo largo del ciclo vital requieren la adaptación de los materiales y métodos empleados. Se incluyen, además, otras recomendaciones de índole ética y práctica consideradas necesarias para la evaluación de los niños desnutridos. **Resultados:** Por último, la estimación de la composición corporal en esta población debe abordarse con cautela, dado que las condiciones clínicas no siempre permiten realizar las mediciones requeridas. **Conclusión:** Esta revisión puede servir como una guía clínica práctica para la realización de mediciones antropométricas en casos de desnutrición infantil.

Palabras Clave: ISAK, Niños, Desnutrición, Composición Corporal.

Introduction

Child malnutrition in general is considered a global problem that affects all countries, and is worsening in regions with extreme poverty, insufficient or difficult-to-access health services, conflicts, and natural disasters among many other factors (Marshall et al., 2021). However, the consequences are the same for all involved. They include stunted growth, poor academic performance, reduced intellectual development, increased burden on health systems, an increase in child mortality, and the inability of individuals to contribute to the economic development of their communities to name just a few. All of this poses a challenge for health professionals (eAcnur, 2020; UNICEF, 2023). According to the 2022 United Nations International Children's Emergency Fund (UNICEF) report on child malnutrition, 148 million children under the age of 5 suffer from stunted growth, 45 million suffer from severe acute malnutrition, and 340 million suffer from macronutrient deficiencies. The same report states that 13,800 children under the age of 5 die each year from preventable causes, with 50% of causes being related to malnutrition (UNICEF, 2023).

Childhood malnutrition refers to deficiencies, excesses, or imbalances in children's energy and/or nutrient intake. On the other hand, child undernutrition, a type of malnutrition, is characterized by stunting (low stretch stature for age) when children suffer from growth retardation because of long-term nutrition deprivation. Undernutrition often results in delayed mental development as well as wasting (a symptom of acute undernutrition) and is usually a consequence of insufficient food intake or a high incidence of infectious diseases, especially diarrhea, increasing in severity in a short time period. The condition can be divided into *moderate*, which is indicated by low body mass for age, and *severe*, low body mass for stretch stature. In diagnosis, these deficiencies are typically determined using anthropometric values compared with reference values as well as clinical parameters (De Onis, 2006). Other frameworks have recently been proposed to evaluate undernutrition including anthropometric measurements plus diet evaluation, but more studies are required (Heemann et al., 2021).

In order to evaluate growth, development and nutritional status of children, it is necessary to have comparable criteria for this age population obtained through a standardized protocol of anthropometric evaluation. There is limited literature on measurement body composition with 4- and 5-component models in children. This could guide scientific and clinical practice and references for future research worldwide, through which growth charts, epidemiological programs and equations based on stature could be used (Baird et al., 2017). The main objective of this work is to Identify and propose the anthropometric variables that should be measured in the population of undernourished children according to ISAK protocol and to determine the necessary modifications and adaptations of anthropometric equipment for each established age group.

Material and Methods

A systematic literature review was conducted to identify the most useful and validated measures, equations and indexes in the anthropometric and body composition assessment of undernourished children, according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses system (PRISMA) (Page et al., 2021). To conduct the systematic review, PubMed, Cochrane Library, EBSCO, PEDro, SPORTDiscuss, Web of Science, Wiley and Dialnet database platforms were consulted using a combination of key words as follows: (((Malnutrition OR Undernutrition OR Nutritional Deficiencies OR Deficit nutrients OR Micronutrients Deficiencies OR Wasting OR Stunting OR Underweight OR Marasmus OR Low weight-for-height OR Low Body mass index) AND (Childhood OR Development OR Child)) AND (Anthropometry OR Kinanthropometry OR Body Composition OR Body constitution OR Somatotype OR Adipose Tissue OR Skeletal muscle OR Skinfold Thickness OR Body Fat Distribution OR Proportionality OR Fat OR Muscle OR Bone OR Body Weight)) NOT (adolescent).

The inclusion criteria were: a) studies which used anthropometric variables; b) publications about undernourished children aged 12 years or younger; c) original papers, systematic reviews, consensus and reports; d) publications in the last ten years (from 2015 to 2025); and e) publications in indexed journals or by recognized health institutions such as the World Health Organization (WHO).

Exclusion criteria were defined as: a) thesis, conference papers, letters to editors, b) non-peer reviewed or unpublished papers; c) studies conducted on adults and adolescents; and d) studies on malnutrition related to obesity.

It should be noted that this document uses a standardized ISAK terminology (2019), even when the original sources use alternative terms (Esparza-Ros et al., 2019). Such as weight to body mass, height to stretch stature and circumferences to girths. More than 1500 studies were identified, but only 263 matches with the inclusion/exclusion criteria. To analyze the anthropometric variables, a classification was defined by age as follows: Group 1: 0 to 12 months; Group 2: 13 to 36 months; Group 3: 3 to 5 years 11 months; Group 4: 6 to 12 years. These groups were divided into two categories: those who were Undiagnosed and those Diagnosed with wasting (low body mass for stretch stature), stunting (low stretch stature for age) or underweight (low body mass for age). Group classification was necessary to identify more appropriate measurements in order to diagnose or monitor undernourished children, and to consider clinical complications such as hypotonia, hypothermia, irritability, or edema.

Results

Ethical Considerations and Protocol Adaptation in the Anthropometric Assessment of Undernourished Children

The anthropometric evaluation of children suffering from undernutrition presents a range of ethical and methodological challenges. These must be addressed with care to ensure that procedures are clinically appropriate, respectful, and aligned with international standards for the protection of vulnerable populations.

Informed Consent and Communication with Caregivers

Before conducting any anthropometric measurements, it is essential to obtain informed consent from a parent or legal guardian. This process must involve a clear, culturally appropriate explanation of the assessment's objectives, methods, potential discomforts, and benefits. Participation should always be voluntary, and caregivers must be made aware that they may withdraw due to any adverse consequences for the child's care (UNICEF, 2013; WHO, 2003).

Respect For The Child's Dignity and Privacy

All procedures should prioritize the child's dignity, privacy, and emotional wellbeing. Evaluations must be conducted in a private, safe and child-friendly environment. Partial removal of clothing, when required, should be done discreetly and always in the presence of a caregiver. Efforts should be made to reduce fear or discomfort through age-appropriate communication and supportive interaction (Basaleem & Amin, 2011).

Protocol Adaptation Based On Clinical Condition

Children with moderate or severe acute undernutrition may present clinical complications such as hypotonia, hypothermia, irritability, or edema, which can interfere with standard measurement techniques. Therefore, the assessment protocol must be adapted accordingly. It should be noted that this document uses a standardized ISAK terminology (2019), even when the original sources use alternative terms (Esparza-Ros et al., 2019).

- Body mass and stretch stature: Calibrated scales and stadiometers appropriate for infants and young children should be used. In severely ill or non-ambulatory children, recumbent length or alternative proxies (e.g., tibia length, arm span) may be required (WHO, 2022)
- Arm relaxed girth at mid-acromiale-radiale point: This point is particularly useful in field settings and should be measured using standardized tapes, such as fiberglass, for minimal discomfort. Care should be taken to avoid pressure in areas with edema or skin lesions.

- Skinfold thickness: As long as there are no skin lesions on the arm or the presence of edema, skinfold measurements can be informative. However, they should be deferred if the procedure may cause distress or harm.
- Assessment: For children in intensive care and who have several conditions, non-essential measurements such as skinfolds or girths should not be taken in order to avoid unnecessary manipulation, focusing instead on stabilizing the child's condition (Sphere Association, 2018).

Training and Sensitization of Health Personnel

Professionals involved in anthropometric assessments must be specially trained not only in technical measurement skills but also in the ethical and psychosocial dimensions of working with undernourished children. This includes child protection principles, emotional support, and the recognition of clinical red flags (UNICEF, 2013; WHO, 2003).

Confidentiality and Ethical Use of Data

All collected data must be treated with strict confidentiality. Identifiable information should be stored securely and used exclusively for clinical decision-making, monitoring, or approved research. Data management must adhere to ethical standards based on the principles of beneficence, non-maleficence, autonomy, and justice, in accordance with international bioethical guidelines established by the Council for International Organizations of Medical Sciences (CIOMS, 2016).

Most Relevant Anthropometric Measurements for Undernourished Children

The proposed variables to be measured are based on the international protocol for anthropometric assessment created by ISAK (Esparza-Ros et al., 2019) and are adapted to the ages to be assessed. The variables can be measured to obtain indices, percentile charts, proportions, skinfold sums, corrected girths, and bone maturation through a formula to predict the skeletal or bone mass.

Table 1 shows the anthropometric measures and indicators identified to evaluate undernourished children. Table 2 shows the same for a population already diagnosed with undernutrition.

Table 1. Anthropometric Measures And Indicators Identified To Evaluate Undernourished Children

Group	Reported anthropometric variables	Indicators used in evaluation of child undernutrition	Growth charts, formula or percentile source tables
Group 1 (0 to 12 months)	**Basic measurements** • Body mass • Stretch stature **Skinfolds** • Triceps • Subscapular **Girths** • Head • Relaxed arm	**Z-scores** • Body mass for age • Stretch stature for age • Stretch stature to body mass for age • Head girth for age **Percentiles** • Triceps skinfold for age • Subscapular skinfold for age	• WHO charts (2007) (UNICEF - WHO, 2024) • CDC charts (US population) (National Center for Health Statistics (CDC), 2024) • Lubchenco, Babson & Benda charts (premature children) (Fenton, 2003)
Group 2 (13 to 36 months)	**Basic measurements** • Body mass • Stretch stature **Skinfolds** • Triceps • Subscapular **Girths** • Head • Relaxed arm	**Z-scores** • Body mass for age • Stretch stature for age • Stretch stature to body mass for age • Head girth for age **Percentiles** • BMI for age (BMI=Body mass (kg)/[stretch stature (cm)]^2) • Triceps skinfold for age • Subscapular skinfold for age • Arm girth for age	• WHO charts (2007) • CDC charts (US population), (National Center for Health Statistics (CDC), 2024) • Frisancho et al., percentile charts for skinfold and relaxed arm/age (Frisancho & Tracer, 1987) • Arm muscle mass (Frisancho, A. R. (1981). *New norms of upper limb fat and muscle areas for assessment of nutritional*

		Body composition ● Arm muscle mass (AMA) AMA(mm)= [(relaxed arm girth (mm) - (3.1416 * Triceps skinfold (mm)))^2] / (4*3.1416) ● Arm Circumference (AC) AC(mm)= ((relaxed arm girth (mm))^2/(4*3.1416) ● Arm fat area (AFA) AFA(mm)= AC-AMA	*status.*
Group 3 (3 to 5 years + 11 months)	**Basic measurements** ● Body mass ● Stretch stature ● Sitting stature **Skinfolds** ● Triceps ● Subscapular ● Thigh ● Calf **Girths** ● Head ● Relaxed arm ● Waist ● Thigh middle ● Calf **Breadths** ● Humerus ● Bi-styloid ● Femur ● Bimalleolar	**Z-scores** ● Body mass for age ● Stretch stature for age ● Stretch stature to body mass for age ● Head girth for age **Percentiles** ● BMI for age (BMI=Body mass (kg)/[stretch stature (cm)]^2) ● Triceps skinfold for age ● Subscapular skinfold for age ● Arm girth for age ● Waist to stretch stature ratio for age (waist girth (cm)/stretch stature (cm)) **Body composition** ● Sum of skinfolds (sum of triceps, subscapular, supraspinale, abdominal, thigh and calf skinfolds in millimeters) ● Arm muscle mass (AMA) AMA(mm)= [(relaxed arm girth (mm) - (3.1416 * Triceps skinfold (mm)))^2] / (4*3.1416) ● Arm Circumference (AC) AC(mm)= ((relaxed arm girth (mm))^2/(4*3.1416) ● Arm fat area (AFA) AFA(mm)= AC-AMA ● Calf corrected girth (calf girth (cm) – (3.1416 x calf skinfold (cm)) **Growth and proportionality** ● Cormic index (sitting height (cm)/stretch stature (cm))	● WHO Z-score (2007) ● CDC charts (US population), (National Center for Health Statistics (CDC), 2024) ● WHO percentile charts for skinfolds/age (2007) ● African-American, European-American, and Mexican-American children waist girth percentile (Fernández et al., 2004) ● Frisancho et al, percentile charts for skinfold and relaxed arm/age (Frisancho & Tracer, 1987) ● Frisancho, A. R. (1981). *New norms of upper limb fat and muscle areas for assessment of nutritional status.*
Group 4 (6 to 12 years)	**Basic measurements** ● Body mass ● Stretch stature ● Sitting stature **Skinfolds** ● Triceps ● Subscapular ● Supraspinale ● Abdominal ● Thigh ● Calf **Girths**	**Z-scores** ● Body mass for age ● Stretch stature for age ● Stretch stature to body mass for age ● Girth of head for age **Percentiles** ● BMI for age BMI=body mass (kg)/[stretch stature (cm)]^2 ● Triceps skinfold for age ● Subscapular skinfold for age ● Arm girth for age ● Waist to stretch stature ratio for age (waist girth (cm)/stretch stature (cm))	● WHO Z-score (2007) ● CDC charts (US population, 2024) ● WHO percentile charts for skinfolds/age (2007) ● Frisancho (2009), percentile charts for skinfold and relaxed arm/age ● African-American, European-American, and Mexican-American children waist girth percentile (2004) ● Fat muscular mass: Slaughter formula (Boye et al., 2002) ● Frisancho, A. R. (1981). *New*

	• Head • Relaxed arm • Waist • Thigh middle • Calf **Lengths** • Radiale-stylion **Breadths and Depths** • Biacromial • Biiliocristal • Humerus • Bi-styloid • Femur • Bimalleolar	**Body composition** • Fat mass FMgirls= 0,735 x (triceps skinfold(mm) + calf skinfold (mm)) + 1,0 FMboys= 0,631 x (triceps skinfold(mm) + calf skinfold (mm)) + 5,1 • Sum of skinfolds (sum of triceps, subscapular, supraspinale, abdominal, thigh and calf skinfolds in millimeters) • Arm muscle mass (AMA) AMA(mm)= [(relaxed arm girth (mm) - (3.1416 * Triceps skinfold (mm)))^2] / (4*3.1416) • Arm Circumference (AC) AC(mm)= ((relaxed arm girth (mm))^2/(4*3.1416) • Arm fat area (AFA) AFA(mm)= AC-AMA • Calf corrected girth (calf girth (cm) – (3.1416 x calf skinfold (cm))) • Bone mineral content (BMC) Boys BMC= 0.043 + (0.018 x AHPV) + (0.039 x radiale-stylion length [cm]) + (0.06 x femur breadth) Girls BMC= 0.077 + (0.07 x AHPV) + (0.032 x radiale-stylion length [cm]) + (0.48 x femur breadth)Bone mineral density (BMD) • Bone mineral density (BMD) Boys BMD= 0.605 + (0.056 x AHPV) + (0.008 x radiale-stylion length [cm]) + (0.022 x femur breadth) Girls BMD= 0.496 + (0.027 x AHPV) + (0.007 x radiale-stylion length [cm]) + (0.019 x femur breadth)	*norms of upper limb fat and muscle areas for assessment of nutritional status.*

Note: Charts are shown in the annexed section

Table 2. Anthropometric Measures and Indexes in Diagnosed with Moderate-Severe or Acute Undernutrition Condition

Group	Reported anthropometric variables	Indicators used in the evaluation of child undernutrition	Growth charts, formula or percentile source tables
Group 1 (0 to 12 months)	**Basic measurements** • Body mass • Stretch stature **Girths** • Head	**Z-scores** • Body Mass for age • Stretch stature for age • Stretch stature to body mass for age • Head girth for age	• WHO charts (2007) • CDC charts (US population, 2024) • Lubchenco, Babson & Benda charts (premature children)
Group 2 (13 to 36 months)	**Basic measurements** • Body mass • Stretch stature **Skinfolds** • Triceps	**Z-scores** • Body mass for age • Stretch stature for age • Stretch stature to body mass for age • Head girth for age	• WHO charts (2007) • CDC charts (US population, 2024) • Frisancho et al., percentile charts for skinfold and relaxed arm/age • Frisancho, A. R. (1981). *New norms of upper limb fat and muscle areas for assessment of nutritional status.*

	Girths ● Head ● Relaxed arm	**Percentiles** ● BMI for age BMI=Body mass (kg)/[stretch stature (cm)]^2 ● Triceps skinfold for age **Body composition** ● Arm muscle mass (AMA) AMA(mm)= [(relaxed arm girth (mm) - (3.1416 * Triceps skinfold (mm)))^2] / (4*3.1416) ● Arm Circumference (AC) AC(mm)= ((relaxed arm girth (mm))^2/(4*3.1416) ● Arm fat area (AFA) AFA(mm)= AC-AMA	
Group 3 (3 to 5 years + 11 months)	**Basic measurements** ● Body mass ● Stretch stature **Skinfolds** ● Triceps **Girths** ● Head ● Relaxed arm	**Z-scores** ● Body mass for age ● Stretch stature for age ● Stretch stature to body mass for age ● Head girth for age **Percentiles** ● BMI for age BMI=Body mass (kg)/[stretch stature (cm)]^2 ● Triceps skinfold for age **Body composition** ● Arm muscle mass (AMA) AMA(mm)= [(relaxed arm girth (mm) - (3.1416 * Triceps skinfold (mm)))^2] / (4*3.1416) ● Arm Circumference (AC) AC(mm)= ((relaxed arm girth (mm))^2/(4*3.1416) ● Arm fat area (AFA) AFA(mm)= AC-AMA	● WHO Z-score (2007) ● CDC charts (US population, 2024) ● Frisancho et al., percentile charts for skinfold and relaxed arm/age ● Frisancho, A. R. (1981). *New norms of upper limb fat and muscle areas for assessment of nutritional status.*
Group 4 (6 to 12 years)	**Basic measurements** ● Body mass ● Stretch stature **Skinfolds** ● Triceps ● Calf **Girths** ● Head ● Relaxed arm ● Calf	**Z-scores** ● Body mass for age ● Stretch stature for age ● Stretch stature to Body mass for age ● Head girth for age **Percentiles** ● BMI for age BMI=Body mass (kg)/[stretch stature (cm)]^2 ● Triceps skinfold for age **Body composition** ● Arm muscle mass (AMA) AMA(mm)= [(relaxed arm girth (mm) - (3.1416 * Triceps skinfold (mm)))^2] / (4*3.1416) ● Arm Circumference (AC) AC(mm)= ((relaxed arm girth (mm))^2/(4*3.1416) ● Arm fat area (AFA)	● WHO Z-score (2007) ● CDC charts (USA population, 2024) ● Frisancho et al., percentile charts for skinfold and relaxed arm/age ● Arm muscle mass (Heymsfield et al., 1982) ● Frisancho, A. R. (1981). *New norms of upper limb fat and muscle areas for assessment of nutritional status.*

		AFA(mm)= AC-AMA ● Calf corrected girth (calf girth (cm) – (3.1416 x calf skinfold (cm)))	

Note: Charts are shown in the annexed section

Adaptations to the Anthropometric Equipment

For children under 12 months of age (Group 1), the use of fiberglass tape is recommended to help prevent skin lesions. In this age group, tape calibration should be verified regularly by cross-checking the fiberglass tape against a brand-new steel (iron) measuring tape and confirming the accuracy of the graduations with a vernier caliper, while ensuring it meets the remaining ISAK specifications for metallic tapes (Esparza-Ros & Vaquero-Cristóbal, 2023). From Group 2 onwards (≥ 12 months), the anthropometric tape must fully comply with the specifications established in the ISAK Manual (e.g., material, graduation, legibility, and other technical requirements) for the corresponding age groups (Esparza-Ros et al., 2019).

Utilize a Lying Height Rod Infantometer to measure recumbent stretch stature in infants less than 12 months of age and in children unable to maintain a standing position. The device should have a measurement range from a minimum of 40 cm to 220 cm with a precision of 0.1 cm (Kiernan & Mascarenhas, 2023).

When evaluating body mass, the parent should hold the child while standing on the scale, and the parent's body mass must then be subtracted from the total measurement to obtain the infant's body mass (Kiernan & Mascarenhas, 2023).

Regarding the remaining anthropometric equipment (anthropometric box, skinfold caliper, small diameter caliper, and large diameter caliper), no modifications are considered necessary, and the specifications should adhere to those established in the ISAK Manual (Esparza-Ros et al., 2019).

Body Composition and Other Derivative Variables in Undernourished Children

There is limited literature on measurement protocols for the study of body composition with 4- and 5-component models in children under 5 years of age, while measurements for age groups 1 and 2 were set according to the UNICEF/WHO universal measurement standards (De Onis, 2006; De Onis et al., 2012; UNICEF - WHO, 2024). However, for age group 2 and subsequent groups, not only was the WHO taken into account, but also anthropometric indicators proposed by the Centers for Disease Control and Prevention (CDC) such as skinfold thickness and girths at arm and calf areas (National Center for Health Statistics (CDC), 2024).

Currently, there are many ways to assess body composition for this population and age groups, such as fat mass index, Z-score values of waist girth and sum of triceps and subscapular skinfolds (Azcorra et al., 2019). To evaluate fat mass index in children 6 to 14 years old (FMI = fat mass [kg]/stretch stature [m]^2), fat mass (FM) can be calculated by equations of Ramirez et al. (2012), directly with the anthropometric variables equation for FM (FM [kg] = -1.067 x sex [male=1, female=0] + 0.458 x triceps skinfold [mm] + 0.263 x body mass [kg] – 5.407) or indirectly with the bioelectrical fat free mass (FFM) equation (FFM[kg] = 0.661 x ((stretch stature [cm])^2/resistance[Ω]) + 0.200 x body mass [kg] - 0.320). Both formulas were developed using deuterium oxide dilution technique (Ramirez et al., 2012).

Freedman et al (2013), evaluate the accuracy of the Slaughter body fat formulas (1988) using Dual Energy X-ray Absorptiometry (DEXA), and recommends evaluating cardiovascular risk by using the triceps and subscapular skinfolds sum equation. Nonetheless, calf and triceps skinfold sum equation is recommended for children 5 to 17 years for estimation overall fat mass from the upper to the lower limb (Freedman et al., 2013; Slaughter et al, 1988).

Measurements from the restricted profile such as calf skinfold and calf girth are important for the z score of corrected girths as well as for triceps skinfold and arm relaxed girth. This last indicator is also an important percentile based on the arm fat area and the arm muscle area according to the references of the percentile tables of Frisancho et al. (Frisancho & Tracer, 1987), and according to a WHO Multicentre Growth Reference Study (De Onis, 2006).

Starting at age 2, waist girth measurement and its percentile are also important, according to the reference tables of Fernandez and Redden et al. as there are specific percentiles in African-, European-, and Mexican-American children (Fernández et al., 2004). Where it is known, bone mineral density (BMD) is also important. Nonetheless, skinfolds such as biceps and triceps have been useful in the important early diagnosis of acute undernutrition in hospitalized children, including those with HIV and cancer (Barr et al., 2011; Gupta et al., 2020; Innes et al., 2013). These skinfolds have been reported as necessary not only in healthy kindergarten children but also in hospitalized undernourished children (Bakshi & Bhandari, 1977; Marrodán et al., 2017; Vijayaraghavan, 1987).

Bone evaluation is complex. While the gold standard to measure bone mineral content and density is the Dual Energy X-ray Absorptiometry (DEXA), which has its own reference values from 2 years onwards, the equipment and high level of training required to perform the measurements are not accessible (Pezzuti el al., 2017; Zanchetta et al., 1995). Deborah Kerr's mass fractionation method emerges as a more affordable alternative based on anthropometric measurements with high reliability and validity to estimate bone mass. In measuring children bone mass from the head is separately adjusted by the Phantom reference. Such adjustment is necessary since the head develops to its full size in early childhood unlike the rest of the body. Specific measurements which require advanced training are head girth, humerus, femur, biacromial, and biiliocristal breadth (Ross & Kerr, 1991). Due to the complexity of measurements in this population, especially bone breadths, there are not yet reference values to evaluate bone mass health with this fractional method. There are other equations which are easier to perform due to the measurements required, such as Rocha's formula: (bone mass [kg] = 3.02 x ((stretch stature [m])^2 x (by-styloid breadth[m]) x (femur breadth [m]) $^{0.712}$)). However, equations were developed for the 17–25-year-old group and there aren't adaptations or validation for children at the time of this revision (Rocha, 1975).

Bone mass evaluation is probably one of the most complex approaches in body composition for children. It can predict bone mineral content and density (BMC and BMD) and can be more affordable, as Gómez-Campos et al. (2017) propose, through a formula that involves anthropometric variables such as radiale-stylion length, femur breadth and the estimation of age at height peak velocity (AHPV) using the Mirwald et al. (2002) technique. The technique, which classifies time in years before or after AHPV occurs (-4,-3,-2,-1,0,1,2,3 years of AHPV). In order to estimate AHPV, stretch stature and sitting height anthropometric measurements are necessary (Gómez-Campos et al., 2017; Mirwald et al., 2002). Equations proposed for these analyses are as follows:

- Boys AHPV= -9.236 + (0.0002708 x (lower limb length [m] x sitting height [m])) – (0.001663 x (age [years] Lower limb length [m])) + (0.007216 x (age [years] x sitting height [m])) + (0.02292 x (body mass [kg]/stretch stature [m]))
- Girls AHPV= -9.376 + (0.0001882 x (lower limb length [m] x sitting height [m])]) – (0.0022 x (age [years] Lower limb length [m])) + (0.005841 x (age [years] x sitting height [m])) – (0.002658 x (age [years] x body mass [kg])) + (0.07693 x (body mass [kg]/stretch stature [m]))

  Note: Lower limb length = stretch stature [cm] - sitting height [cm]
- Boys BMD= 0.605 + (0.056 x AHPV) + (0.008 x radiale-stylion length [cm]) + (0.022 x femur breadth)
- Girls BMD= 0.496 + (0.027 x AHPV) + (0.007 x radiale-stylion length [cm]) + (0.019 x femur breadth)
- Boys BMC= 0.043 + (0.018 x AHPV) + (0.039 x radiale-stylion length [cm]) + (0.06 x femur breadth)
- Girls BMC= 0.077 + (0.07 x AHPV) + (0.032 x radiale-stylion length [cm]) + (0.48 x femur breadth)

Referential values can be found in the original paper (Gómez-Campos et al., 2017). Also, functional measurements such as hand grip strength have been correlated to BMD and BMC and are useful to predict bone fragility (Alvear-Vasquez et al., 2020).

Conclusion

Anthropometric assessment of undernourished children must be a simple and easily interpreted process that can be applied worldwide. However, it is more complex than ordinary evaluation because there are often clinical conditions that restrict some measurements, such as skinfolds and some girths in the presence of edema or hypotonia. Additionally, in caring for this population, health personnel need special training by identifying what, which, when and how to measure, since protecting the main objective is the child's integrity is of utmost importance. As such, there are many ethical and methodological adaptations that must also be considered. When conducting anthropometric measurements in children, there are a wide range of variables to be considered, such as clinical illness, neuromuscular control associated with different stages of growth and development, as well as issues of privacy, ethics, and legal dependency on a caregiver. The authors suggest considering all recommendations before beginning any measurement. While body composition is a useful indicator of status and progression in the clinical intervention of child undernutrition, undernourished children intervention in under clinical conditions, it has its limitations and evaluators should use it with caution. Therefore, a simple but efficient way to evaluate the characteristics of different conditions that characterize child undernutrition (wasting, stunting or underweight, using as the basis the ISAK protocol as a standardized method, with adaptations when necessary. To analyze and perform the diagnosis, the use of local or national references, if available, could be considered useful as a complement to the international charts or percentiles from the World Health Organization.

References

Alvear-Vasquez, F., Gomez-Campos, R., Pezoa-Fuentes, P., Urra-Albornoz, C., Caceres-Bahamondes, J., Luarte-Rocha, C., Sulla-Torres, J., Cossio-Bolaños, M.A. (2020). El Flujo espiratorio Máximo y la Fuerza de prensión Manual Predicen La Salud Ósea De Niños Y Adolescentes (Maximum Expiratory Flow and Handgrip Strength Predict Bone Health in Children and Adolescents). *Retos*, 38: 123-128. https://doi.org/10.47197/retos.v38i38.71786

Azcorra, H., Rodríguez, L., Banik, S.D., Bogin, B., Varela-Silva, M.I., Dickinson, F. (2019). Caesarean Birth and Adiposity Parameters in 6- to 8-Year-Old Urban Maya children from Two Cities of Yucatan, Mexico. *American Journal of Human Biology*, 31(2): e23217. https://doi.org/https://doi.org/10.1002/ajhb.23217

Baird, J., Walker, I., Smith, C., Inskip, H. (2017). Review of Methods for Determining Pubertal Status and Age of Onset of Puberty in Cohort and Longitudinal Studies. *London, UK: CLOSER*.

Bakshi, A.C., Bhandari, N. R. (1977). Assessment of Nutritional Status of Pre-School Children in Bhopal. *Indian Pediatrics*, 14(8): 615–623. https://www.cabidigitallibrary.org/doi/full/10.5555/19771463389

Barr, R., Collins, L., Nayiager, T., Doring, N., Kennedy, C., Halton, J., Walker, S., Sala, A., Webber, C. (2011). Nutritional Status at Diagnosis in Children with Cancer. 2: An Assessment by Arm Anthropometry. *Journal of Pediatric Hematology/Oncology*, 33(3): e101-e104. https://doi.org/10.1097/mph.0b013e3182002a65

Basaleem, H.O., Amin, R.M. (2011). Integrated Management of Childhood Illness in Lahej, Yemen: A qualitative analysis from the perspective of health providers. *Eastern Mediterranean Health Journal*, *17*(2): 101–108. https://iris.who.int/handle/10665/118086

Boye, K.R., Dimitriou, T., Manz, F., Schoenau, E., Neu, C., Wudy, S., Remer, T. (2002). Anthropometric assessment of muscularity during growth: estimating fat-free mass with 2 skinfold-thickness measurements is superior to measuring midupper arm muscle area in healthy prepubertal children123. *The American Journal of Clinical Nutrition*, 76(3): 628–632. https://doi.org/10.1093/ajcn/76.3.628

Council for International Organizations of Medical Sciences (CIOMS). (2016). *International ethical guidelines for health-related research involving humans: Prepared by the Council for International Organizations of Medical Sciences (CIOMS) in collaboration with the World Health Organization (WHO)*. Council for International Organizations of Medical Sciences. https://doi.org/https://doi.org/10.56759/rgxl7405

De Onis, M. (2006). Reliability of anthropometric measurements in the WHO Multicentre Growth Reference Study. *Acta Paediatrica*, 95(S450): 38–46. https://doi.org/10.1111/j.1651-2227.2006.tb02374.x

De Onis, M., Onyango, A., Borghi, E., Siyam, A., Blössner, M., Lutter, C. (2012). Worldwide implementation of the WHO Child Growth Standards. *Public Health Nutrition*, 15(9): 1603–1610. https://doi.org/10.1017/S136898001200105X

eAcnur. (2020). *Desnutrición infantil en el mundo*. https://eacnur.org/es/actualidad/noticias/emergencias/desnutricion-infantil-en-el-mundo

Esparza-Ros, F., Vaquero-Cristóbal, R. (2023). Antropometría: Fundamentos para la aplicación e interpretación. *Aula Magna, McGraw Hill*. https://books.google.com.mx/books?id=K3jCEAAAQBAJ

Esparza-Ros, F., Vaquero-Cristóbal, R., Marfell-Jones, M. (2019). Protocolo Internacional Para La Valoración Antropométrica*, Sociedad Internacional para el Avance de la Cineantropometría, ISAK, 2019,* 154. https://books.google.com.mx/books?id=eRqfzgEACAAJ

Fenton, T.R. (2003). A New Growth Chart for Preterm Babies: Babson and Benda's Chart Updated with Recent Data and a New Format. *BMC Pediatrics*, 3: 13. https://doi.org/10.1186/1471-2431-3-13

Fernández, J.R., Redden, D.T., Pietrobelli, A., Allison, D.B. (2004). Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *The Journal of Pediatrics*, 145(4): 439–444. https://doi.org/10.1016/j.jpeds.2004.06.044

Freedman, D.S., Horlick, M., Berenson, G.S. (2013). A comparison of the Slaughter skinfold-thickness equations and BMI in predicting body fatness and cardiovascular disease risk factor levels in children. *The American* *journal of clinical nutrition*, 98(6): 1417-1424.

Frisancho, A.R., Tracer, D. P. (1987). Standards of arm muscle by stature for the assessment of nutritional status of children. *American Journal of Physical Anthropology*, *73*(4): 459–465. https://doi.org/10.1002/ajpa.1330730408

Gómez-Campos, R., Andruske, C.L., Arruda, M.D., Urra Albornoz, C., Cossio-Bolaños, M. (2017). Proposed equations and reference values for calculating bone health in children and adolescents based on age and sex. *PloS one*, 12(7): e0181918. https://doi.org/10.1371/journal.pone.0181918

Gupta, P.M., Wieck, E., Conkle, J., Betters, K.A., Cooley, A., Yamasaki, S., Laibhen-Parkes, N., Suchdev, P. S. (2020). Improving assessment of child growth in a pediatric hospital setting. *BMC Pediatrics*, 20(1): 419. https://doi.org/10.1186/s12887-020-02289-1

H Heemann, M., Kim, R., Vollmer, S., Subramanian, S.V. (2021). Assessment of undernutrition among children in 55 low-and middle-income countries using dietary and anthropometric measures. *JAMA network open*, 4(8): e2120627. https://doi.org/10.1001/jamanetworkopen.2021.20627

Heymsfield, S.B., McManus, C., Smith, J., Stevens, V., Nixon, D.W. (1982). Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. *The American journal of clinical nutrition*, 36(4): 680–690. https://doi.org/10.1093/ajcn/36.4.680

Innes, S., Schulte-Kemna, E., Cotton, M.F., Zöllner, E. W., Haubrich, R., Klinker, H., Sun, X., Jain, S., Edson, C., van Niekerk, M., Innes, E. R., Rabie, H., Browne, S.H. (2013). Biceps Skin-fold Thickness May Detect and Predict Early Lipoatrophy in HIV-infected Children. *The Pediatric Infectious Disease Journal*, *32*(6):e254-e262. https://doi.org/10.1097/INF.0b013e3182814b30

Kiernan, B.D., Mascarenhas, M. (2023). Growth Assessment and Its Significance. *In: Vachani, J.G. (eds) Failure to Thrive and Malnutrition.* Springer International Publishing, Cham, 33–72. https://doi.org/10.1007/978-3-031-14164-5_3

Marrodán, M.D., González-Montero de Espinosa, M., Herráez, Á., Alfaro, E.L., Bejarano, I.F., Carmenate, M., Lomaglio, D.B., López-Ejeda, N., Martínez, A., Mesa, M.S., Pérez, B.M., Meléndez, J.M., Moreno-Romero, S., Pacheco, J.L., Vázquez, V., Dipierri, J.E. (2017). Development of subcutaneous fat in Spanish and Latin American children and adolescents: Reference values for biceps, triceps, subscapular and suprailiac skinfolds. *HOMO*, 68(2): 145–155. https://doi.org/10.1016/j.jchb.2017.02.003

Marshall, A. I., Lasco, G., Phaiyarom, M., Pangkariya, N., Leuangvilay, P., Sinam, P., Suphanchaimat, R., Julchoo, S., Kunpeuk, W., Zhang, Y. (2021). Evidence on Child Nutrition Recommendations and Challenges in Crisis Settings: A Scoping Review. *International journal of environmental research and public health*, *18*(12), 6637. https://doi.org/10.3390/ijerph18126637

Mirwald, R.L., Baxter-Jones, A.D., Bailey, D.A., Beunen, G.P. (2002). An assessment of maturity from anthropometric measurements. *Medicine & science in sports & exercise*, *34*(4), 689-694.

National Center for Health Statistics (CDC). (2024). *Growth charts.* https://www.cdc.gov/growthcharts/index.htm

National Center for Health Statistics (CDC). (2025). *NANHES survey I.* https://www.cdc.gov/nchs/nhanes/nhanes1/default.aspx

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart , L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, 372: n71. https://doi.org/10.1136/bmj.n71

Pezzuti, I.L., Kakehasi, A.M., Filgueiras, M.T., de Guimarães, J.A., de Lacerda, I.A.C., Silva, I.N. (2017). Imaging methods for bone mass evaluation during childhood and adolescence: an update. *Journal of Pediatric Endocrinology and Metabolism*, 30(5): 485-497. https://doi.org/10.1515/jpem-2016-0252

Ramírez, E., Valencia, M. E., Bourges, H., Espinosa, T., Moya-Camarena, S. Y., Salazar, G., Alemán-Mateo, H. (2012). Body composition prediction equations based on deuterium oxide dilution method in Mexican children: a national study. *European Journal of Clinical Nutrition*, 66(10): 1099-1103.

Rocha, M.S.L. (1975). Peso ósseo do brasileiro de ambos os sexos de 17 a 25 años. *Arquivos de Anatomía e Antropología*, 1: 445–451.

Ross, W.D., Kerr, D.A. (1991). Fraccionamiento de la masa corporal: un nuevo método para utilizar en nutrición clínica y medicina deportiva. *Apunts*, 28: 175–188. https://dialnet.unirioja.es/servlet/articulo?codigo=6305062

Slaughter, M.H., LOHMAN, T.G., Boileau, R., HORSWILL, C.A., STILLMAN, R.J., Van Loan, M.D., Bemben, D.A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human biology*, 60(5): 709-723. https://www.jstor.org/stable/41464064

Sphere Association. (2018). *The Sphere Handbook: Humanitarian charter and minimum standards in humanitarian response* (4ª edition). Practical Action Publishing. https://www.spherestandards.org/handbook-2018/

UNICEF - WHO. (2024). *The UNICEF-WHO- World Bank Joint Child Malnutrition Estimates (JME) standard methodology Tracking progress on SDG Indicators*, 2(1). https://www.who.int/publications/i/item/9789240100190

UNICEF, U. N. C. F. (2013). *Improving child nutrition: The achievable imperative for global progress*. https://data.unicef.org/resources/improving-child-nutrition-the-achievable-imperative-for-global-progress/

UNICEF, U. N. C. F. (2023). *Causas de la Desnutrición infantil*. https://www.unicef.es/causas/desnutricion-infantil

Vijayaraghavan, K. (1987). Anthropometry for assessment of nutritional status. *The Indian Journal of Pediatrics*, *54*(4), 511–520. https://doi.org/10.1007/BF02749045

WHO, W. H. O. (2022). *Training course on the inpatient management of severe acute malnutrition: course director's guide* (W.H.O.(WHO)(ed.)). WHO. https://www.who.int/publications/i/item/9789240029781

WHO, W.H.O. (2003). Guiding principles for feeding infants and young children during emergencies. https://iris.who.int/handle/10665/42710

WHO, W.H.O. (2025). *Child growth standards*. https://www.who.int/tools/child-growth-standards/standards

Zanchetta, J.R., Plotkin, H., Filgueira, M.A. (1995). Bone mass in children: normative values for the 2–20-year-old population. *Bone*, 16(4): S393-S399. https://doi.org/10.1016/8756-3282(95)00082-o

Acknowledgement

This study was funded by the International Society of Kinanthropometry (ISAK).

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Informed Consent Statement

All the athletes included in the study provided written informed consent.

About the License