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Evaluation of body composition in neonates and infants

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Summary A better understanding of the nutritional needs of both healthy and sick infants is important. Not only does too much or too little nutrition during early life have long-term effects on health, but periods of rapid growth during the first year of life also have long-term consequences. Knowledge of the changes in body composition in early life can help to better define nutritional needs at these ages. Several methods are available for measuring body composition of neonates and infants. Most focus on an assessment of either body fatness or bone mineralization; only a few can monitor the quality of the non-fat lean tissues. This paper provides an evaluation of the different approaches currently available to monitor infant body composition, identifying both their strengths and limitations.

Introduction

Both the quality and quantity of nutrient intake during early life can have long-term health consequences. Impaired or excess weight change, as well as periods of rapid 'catch-up' growth, have been associated with the increased risks for adult-onset diseases.[1,2] Monitoring changes in body weight, body length, and head circumference has become relatively routine for many pediatric practitioners. Plotting these changes on growth charts allows one to gauge an infant's progress compared with national or international standards.[3,4] Standardized weight-for-length indices are also available.[5] In recent years, however, a number of non-invasive methods have emerged that can provide additional information about the composition of the body that may aid in the nutritional management of infants.[6,7]

Body composition models

The simplest, and most frequently used, body composition model divides body weight (Wt) into two compartments: fat mass (FM) and fat-free mass (FFM). This model was originally derived specifically for the assessment of body fatness, defined as body fat expressed as a percentage of body weight; the FFM compartment was used only as part of the intermediate steps used in the calculation of the FM value. However, more advanced multiple-compartment models have divided FFM into its various components (Fig. 1). These range from a grouping based on simple molecules to those of metabolic function and anatomical structure.[8] The molecule or nutrition model, for example,

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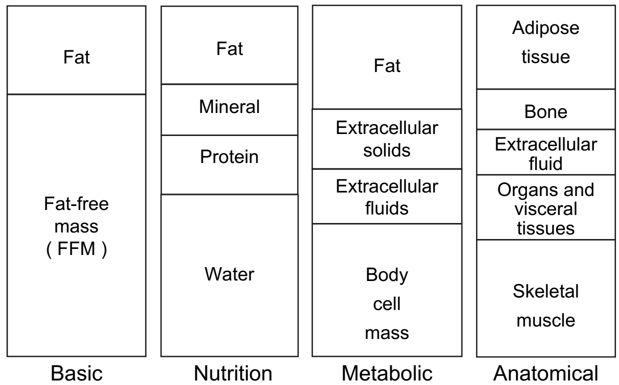

Figure 1 Different models of body composition used for infants.

partitions FFM into water, proteins, and minerals. Body glycogen is also part of this model; it is relatively small compared with the other compartments, and cannot be measured directly. For the metabolic model, FFM is defined in terms of its active metabolizing tissues, called the body cell mass, and its extracellular water and solids, the latter consisting mainly of bone. The anatomical model, as its name implies, separates the body on the basis of the functional role of tissues. It is to be noted that most body composition methods cannot measure body fat directly, but instead derived an estimate for FFM, that is subtracted from body weight to obtain FM.

Body water measurements

For the nutrition model, total body water (TBW) is also the main component of FFM. Hence, if body water can be measured and the ratio of TBW to FFM is known, then FM can be calculated:

$$FM = Wt - k_1 \times TBW$$

This approach is reasonably consistent for healthy adults because the hydration of lean tissues remains relatively constant ($k_1 = 0.732 \pm 3\%$) at these ages. However, for neonates and infants, FFM hydration is not constant ($k_1 = 0.90–0.77$), decreases immediately after birth, and continues to show a decline throughout healthy infancy. Sick infants can have erratic fluctuations in body water. Hence, results obtained with any method based on the direct or indirect measurement of body water, coupled with the use of the two-compartment model, should be used with some caution.

Body water is also the major contributor to body weight. To measure total body water (TBW) directly, an infant is orally administered a small amount of water, labeled with deuterium or ^{18}O, both of which are non-radioactive tracers. Typically, spot urine samples are collected before the oral dose and for several hours after the dose. Samples are analyzed using isotope-ratio mass spectroscopy (IRMS) or Fourier-transformed infrared spectroscopy (FTIR). The turn-around time between collection of the samples and the TBW results is highly dependent on the availability of the analytical analysis. Also, repeat measurements should be done only after the tracer from a previous measurement has cleared the body, typically 10–14 days for infants. This restriction limits the frequency with which TBW can be measured. A clear advantage of the TBW assay, however, is that it can be used in remote geographical locations around the world, with the samples sent to a central laboratory for later analyses.

To overcome the limitations with the dilution-based assays for TBW, methods based on the general electrical properties of hydrated tissues have been developed. The two most common techniques are bioelectrical impedance analysis (BIA) and total body electrical conductivity (TOBEC). For BIA, the theory is that when a weak alternating electrical current is passed through the body, the body's resistance to the current is inversely proportional to its hydrated tissue mass, adjusted for body length. For this measurement, electrodes are usually attached at the foot and hand on the same side of the body. The measured resistance is converted to an estimate of FFM, and used with the two-compartment model to calculate FM.[6,7] The BIA method has been popular, partly because the instruments are relatively inexpensive and portable, and because the measurement can be made frequently.[9] However, studies in infants have not shown any significant advantage over basic anthropometric measurements.[6,10] Also, the algorithms used to calculate FFM appear to be instrument and population specific. An alternative BIA approach is to use a parameter, called the phase angle, which is reported to adjust for changes in abnormal hydration.[11] This approach has not been fully evaluated for healthy infants and needs investigation of its clinical validity.

For the TOBEC assay, the premise is that when an infant is placed within an external uniform electromagnetic field, perturbations in the external field are generated and are proportional to the volume of the body's hydrated lean tissues.[12] Infant/toddler-sized commercial TOBEC instruments have been in use for a number of years but their sensitivity is not sufficient to measure smaller or preterm infants. The measurement procedure is easy, takes only a few minutes to complete, has good precision, can be repeated as often as needed, and the results are immediately available. The physical size of the instrument, however, prohibits its portability. One study has reported body composition reference values for infants using the TOBEC measurement.[13] However, this technology is slowly being phased out because these instruments are no longer being manufactured.

Body volume and density measurements

Probably the most well-known technique for measuring body composition is underwater weighing. As the name implies, the subject is weighed while totally submerged underwater after having exhaled as much air as possible from his or her lungs. This method cannot be used with infants. However, an alternate methodology, called air-displacement plethysmography (ADP), has been developed and used successfully for body composition measurements in infants.[14,15] The instrument, called the PEA POD, has been validated in several studies of healthy infants, with the deuterium dilution method for body water and an advanced four-compartment body composition model serving as the references.[16,17] The PEA POD measurement is easily performed, and the infant is not restrained during the 2-min procedure. The measurement precision (<0.5%) for FM is excellent.[16,17] However, further testing is needed to determine which reference model to use with preterm