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Conference Report

Healthy status and energy balance in pediatrics

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Abstract. During growth, the human body increases in size and changes proportion of various components due to hormones mediators. Nutritional status is the result of introduction, absorption and utilization of the nutrients and it has a new definition in the relationship between nutritional status and healthy status. In this view energy balance, body function and body composition are three entities correlated each other. This mini-review article examines issues and techniques specifically related to a pediatric population in the field of body composition and energy expenditure. It is broadly divided into two sections. The first section discusses body composition measurements underlying principles, advantages, disadvantages and consensus. The second section reviews energy expenditure and physical activity measurement techniques. In conclusion general clinical suggestions are offered regarding pediatric body composition, healthy status and energy balance. (www.actabiomedica.it)

Key words: Pediatric, body composition, physical activity, growth, energy expenditure, nutrition

Introduction

During growth, the human body increases in size and changes proportion of various components due to hormones mediators (1). Growth is a complex, biological process regulated by multiple factors. These factors include genetic, nutrition intake, physical activity, age, gender, and endocrine balance, all of which influence a child's height and body composition during the growth years (2). Clinical assessment of growth and nutritional status is enhanced by accurate measurement of body composition (3). Better understanding body composition and factors influencing its development can improve prediction of adult status and help to propose strategies for reducing the risk factors of various diseases (e.g. obesity). Whatever the reason for assessing body composition, nutritionists and clinicians in health-related fields should have a general understanding of the most commonly used techniques for assessing body composition in pediatric subjects (4).

Nutritional status is the result of introduction, absorption and utilization of the nutrients hand has a new definition in the relationship between nutritional status and healthy status. In this view energy balance, body function and body composition are three entities correlated each other (5) (Figure 1).

This mini-review article examines issues and techniques specifically related to a pediatric population in the field of body composition and energy expenditure. The article is broadly divided into two sections. The first section discusses body composition measurements underlying principles, advantages, disadvantages and consensus. The second section reviews energy expenditure and physical activity measurement techniques. In conclusion, fundamental issues in the field

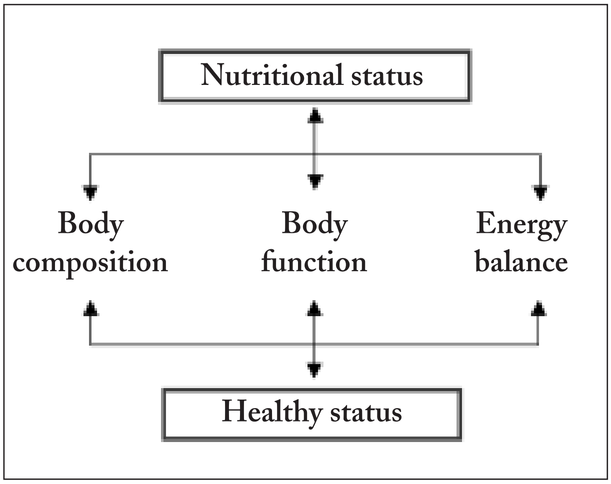

Figure 1. Definition of nutritional status

of body composition and energy expenditure in children and adolescents are examined particularly with reference physical activity.

Body composition

Body composition studies include quantification and distribution of fat and fat free mass and their variation as a function of gender, race and age. Quantifying the main components of the body is fundamental in order to describe deficiency or excess that are associated with the risk or onset of disease. Measurement of body mass in children is extremely challenging because we do not have direct measurements except *in vivo* neutron activation analysis and chemical analysis of the cadaver. There are, however, several indirect methods to measure fat and fat free mass, all of which have assumptions and age specific considerations (4). In the following section we will review, the techniques that are considered appropriate for research and clinical application in children.

Anthropometry

Anthropometry represents a group of inexpensive, non invasive methods available to assess size, shape and composition of human body.

Body Mass Index (BMI)

Among several weight for height indices reported in the pediatric literature Body Mass Index (BMI), weight in kilogram divided height in meter squared (BMI= kg/m^2), may provide childhood fat estimates in large epidemiological studies. BMI shows significant variations during childhood; that is the reason why, age and gender specific reference standards must be used, and in adolescents the pubertal status should also be evaluated (6).

Weight and height reference charts are important for monitoring excess weight and subsequently fatness. BMI reflects both fat and fat free mass and is not a direct measure of adiposity, thus it does not provide a qualitative measure (i.e., it does not reflect ones percent fat) of ones overall body weight. There is a good correlation between fat and BMI in groups but the variation is large and BMI cannot predict fatness in individual subjects. May be BMI is a surrogate measurement of adiposity but it lacks adequate sensitivity and specificity and could misclassify a child as obese or non-obese (7).

Skinfolds

A long standing method for determining body density, fat free mass, fat mass and percent body fat is skinfold measurement. This method is widely applied and can be used alone in evaluating nutritional status or incorporated into prediction equation formulas for body component estimation (8). This technique uses special calipers to “pinch” and ascertain the thickness of skinfold at specific body sites (9). The most useful skinfold thickness in pediatric populations is the triceps and subscapular sites.

Circumferences

Pediatric body composition can be estimated by measuring the size and proportion of the human body. For this reason circumferences and skeletal breadth measurements are used. This method is based on the principle that circumferences reflect fat mass and fat free mass, and skeletal size is related to lean body mass (3). Circumferences at the waist, hip and thigh are used to predict body fat distribution and waist and hip are good predictors of intra-abdominal fat (10). Waist circumference is associated with cardiovascular risk factors and with metabolic syndrome (11).

Air-Displacement Plethysmography

Air displacement plethysmography (ADP) by BOD POD (Life Instrument Systems, Concord CA, USA) is a body composition method that measures body volume and body density. The body density can then be used to calculate an estimate of total body fat and fat free mass. This method has excellent potential to become a routine and accepted body composition method in children (12)

Bioimpedance Analysis (BIA)

Using bioimpedance analysis methods (BIA) the electrical impedance of the body is measured introducing a small alternating electrical current into the body and measuring the potential differences that result. The impedance magnitude (Z) is the ratio of the magnitude of the potential difference to the magnitude of the current. Alternating electrical current flows through the body by several different physical characteristics (13). Tissues rich in water and electrolytes offer considerably less resistance to passage of an electrical current than do lipid-rich adipose tissue. Conceptually, a human devoid of adipose tissue would have minimum impedance what would increase to a maximum when all lean tissue was replaced by fat-filled adipose tissue (8, 13). A limitation of BIA is that it provides an estimate of total body water (TBW). Age or pubertal specific equations have been recommended, because age related differences in electrolyte concentration in the extra cellular space relative to the intracellular space may alter the relationship between bioelectrical resistance and TBW (14). Also, race-specific prediction equations for fat free mass have been developed (8, 13, 14).

An important issue is that subject measurement conditions must be rigorously standardized in order to obtain accurate body composition estimates. Room and subject temperature, position of the patient, correct electrode placement, the use of appropriate equations and several other factors (e.g., eating or drinking) influence measured impedance and must be standardized to the possible extent during BIA measurements (3).

Dual energy X-ray Absorptiometry (DXA)

Recent advances in techniques for measuring body composition have provided dual energy X-ray Absorptiometry (DXA) for assessment of whole body as well as regional measurements of bone mass, lean mass and fat mass (15, 16).

DXA is based on the exponential attenuation due to absorption by body tissues of photons emitted at two energy levels (40 and 70 keV). Subjects lie on their backs on a padded table wearing a hospital gown. The counter moves in a raster pattern above the subject's body from head to foot and counts attenuation rates of photons from the X-ray source within the table. DXA is commonly used in the assessment of body composition in children. The reason is because it is easy to be performed and has advantages over other laboratory techniques that estimate whole body as well as regional composition. The greatest advantage of DXA may be the ability to assess regional body composition (e.g., arms, trunk, and legs). Nutritional status of diseases and growth disorders can be evaluated by analyzing the individual compartment of the body and could offer a new method for the study of skeletal maturation, mineral homeostasis, environmental and nutritional factors involved in development (17).

Imaging Methods

Computerized axial tomography (CT) and magnetic resonance imaging (MRI) provide investigators the opportunity to evaluate in pediatric tissue-system level in vivo analysis (18). Computerized axial tomography and MRI can produce cross-sectional high-resolution images and multiple cross-sectional images can be used to reconstruct tissue volumes including total, subcutaneous and visceral adipose tissue, skeletal muscle, brain, heart, kidney, liver, skin, and bone (4). Imaging techniques could explain the physiology of intra abdominal adipose tissue and its relation to health and ultimately the associations between intra-abdominal adipose tissue and metabolic factors (10). None of the currently available methods can assess tissue-system level body composition components with the same accuracy as CT and MRI. The early accumulation of intra-abdominal adipose tissue in childhood is clinically relevant, because there are significant relationships with adverse health, including dyslipidemia and glucose intolerance, in obese children (11). The accuracy of the measurements that we have with CT and MRI should help to understand ethnic differences in fat distribution as well as gender differences (10).

Energy expenditure

There are three components that comprise ones total energy expenditure (TEE). First and the largest component is resting metabolic rate (RMR) and comprises ~65% of the total energy consumed in a twenty-four hour period (19). One's RMR refers to the energy expended at rest to maintain basic physiologic function (e.g. respiration, muscle tone, heart rate, brain function, and maintaining body temperature). It is common practice for RMR and basal metabolic rate (BMR) to be used interchangeably. The second, but most varied source of ones TEE, is activity related physical activity and typically ranges from 15 to 30% of ones TEE. Physical activity can be anything that requires body movement and muscular contraction e.g. organized sports, exercise, walking, fidgeting, or even sitting. The last component of TEE is the thermic effect of feeding (TEF) or meal-induced thermogensis. After eating a meal metabolism rises in part to digest, metabolize, and store food stuffs that have been just consumed, this rise in metabolism makes up ~ 7 – 13% of ones TEE (19, 20).

Energy expenditure is typically measured using indirect calorimetry, although it can be directly measured. In a clinical setting, energy expenditure is meaningful only when it is expressed as a calorie, i.e. the amount of heat necessary to raise the temperature of one liter of water 1°C, from 14.5 to 15.5°C. Direct calorimetry involves the measurement of actual heat production, though highly accurate and precise, the method is impractical for human metabolism studies and is rarely used today.

Indirect calorimetry typically involves the measurement of expiratory gases (O_2 and CO_2) at the mouth, specifically the amount of O_2 consumed and CO_2 produced when a food source is oxidized and is based on the caloric equivalent of 1 liter of O_2 liberating ~ 5 calories (21).

Indirect calorimetry can be used to measure activity related energy expenditure or aerobic fitness utilizing a mask or mouth piece from a variety of commercially available metabolic systems, as well as resting energy expenditure with a canopy hood or lightweight/portable systems that use either a mask or mouth.

Respiratory gas analysis by indirect calorimetry provides two valuable pieces of information for exercise physiologists and clinical researchers. It allows for the respiratory exchange ratio (RER) to be calculated (VCO_2 produced / VO_2 consumed) giving crucial information on substrate utilization, and it provides a gauge to the level of exertion put out by the subject, i.e. the degree at which a subject is reaching the maximum ability to consume oxygen (i.e. VO_2 max or ones maximal aerobic capacity).

Another form of indirect calorimetry and less common than blood and breathe, is the double-labeled water technique which utilizes stable isotope procedures techniques in the measurement of CO_2 (22, 23).

Physical activity

Physical activity is a rather ambiguous term loosely used to describe body movement or activity and is characterized by type (i.e. organized vs. recreational vs. occupational, aerobic vs. anaerobic), intensity (i.e. heart rate), duration (i.e. time), frequency (i.e. minutes per day and days per week), and surrounding environmental and social conditions (24, 25).

Unlike energy expenditure, physical activity does not measure energy expended (calories); it measures past activity, steps, frequencies, accelerations, counts, habits, and trends that ultimately are converted to something more meaningful than calories, this is because physical activity is measured with questionnaires, motion sensors (e.g. pedometers and accelerometers), observation booths, heart rate, and diaries.

Questionnaires

Most questionnaires (recalls, diaries, and history surveys) involve the subject (or parent) to use self report of past activity.

One must not forget that these qualitative instruments (questionnaires) having real value and meaning must be converted into a quantifiable measure: for example, it is quite difficult to translate qualitative information (e.g. playing kickball in gym class for twenty minutes or playing hop scotch for one hour) to a quantifiable outcome (e.g. calories burned for this period of time) (10). This conversion relies on the use of activity factors or intensity factors which are interrelated to metabolic equivalents (MET) (10). One MET by definition is the amount of oxygen consumed per body weight at rest (3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$), thus a person playing at 5 METs would require 5 times as much oxygen as they would at rest or stated another way they are playing at an intensity that is 5 times greater than being in a rested state. Once the MET level is determined calories, can be calculated because 1 MET = ~ ($1 kcal \cdot kg^{-1} \cdot h^{-1}$).

Movement based techniques

The gold standard to evaluate physical activity in children is to directly observe at play through a one way mirror or glass (26). Clearly, this approach is time consuming and limits the number of children that can be studied while restricting the play area that the children can engage in activity, thus alternative approaches have been developed that are easier to implement while giving the children freedom to move about freely and unimpeded (20).

The two most commonly used movement based devices are pedometers and accelerometers. Principally, pedometers measure the number of steps taken and are generally worn on the hip but could be worn on the ankle, where as accelerometers measure the change in acceleration, they too are typically worn at the hip. Pedometers and accelerometers measure vertical displacement only from ambulation, thus certain types of activities (e.g. bicycling, skate boarding, block playing, and swimming) are missed, nonetheless they are an invaluable tool in the assessment of physical activity. Accelerometers measure the bodies acceleration and have the capability to differentiate between different intensities while having the ability to store the data for a period of up to a week (20).

Heart Rate Monitors

Heart rate monitors provide an objective measure of physical activity and have been used for some time in children (27, 28). This is because physical activity and energy expenditure have a linear relationship with VO_2 (i.e. energy expenditure), though there are limitations using this approach because the heart rate VO_2 relationship can be affected by age, gender, training status, ambient temperature, and motivation not to mention mental stresses (e.g. anxiety, excitement, and sadness) (29).

Conclusion

Given the literature review in this chapter, the following general clinical suggestions are offered regarding pediatric body composition, healthy status and energy balance.

1. Effects of growth, aging, nutrition, and physical activity in body composition and energy balance:
   a. Overfeeding of normal and under nutrition person's results in an increase in lean body mass and in increase of fat mass.
   b. Use of androgenic steroids and exercise could increase lean body mass but not body fat.
   c. Feeding a low energy diet to obese and nonobese subjects decreas both lean body mass and body fat.
   d. Feeding a high energy, low protein diet will increase both body fat with minor change in lean body mass.
2. Taking into account the various factors (e.g., growth, diet, physical activity, hormones) that influence body composition it may be possi-

ble to control growth development. It could be possible also to control several parameters in order to reduce risk factors of various diseases (e.g., high blood pressure, diabetes, obesity).

3. There is no single body composition method as well as energy expenditure, which is the "best" for pediatric samples. The clinicians and the researchers need to know the practical considerations of body composition and energy expenditure assessment with the limitations and strengths of the methods to limit measurement errors (30).

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