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Assessment of Fitness in Cerebral Palsy: Focus in Body Composition and Balance

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Abstract

In Cerebral Palsy (CP) increased stretch reflexes and muscle tone, weakness of involved musculature, and severe limitation of movement reduce the capacity to perform normal movements creating ambulation barriers limiting physical activity. The dependency on mobility devices, common in all disabilities, and the frequent periods of immobilization after multiple operative procedures contribute to the hypo-activity status of such children. Under these conditions, body composition may be significantly compromised. The evaluation of balance in Cerebral Palsy (CP) is an extremely difficult and complex procedure. Berg Balance Scale (BBS), Time Up and Go (TUG) and Bruininks -Oseretsky Test of Motor Proficiency (BOTMP) are considered to be reliable and valid tests, able to objectively define the quantitative mutation of the balance of the child in test with CP.

Keywords: Cerebral palsy; Body composition; Bone; Fat; Muscle; DXA; Balance; TUG; BBS; BOTMP

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Introduction

In disabled subjects body composition is alternated because of immobilization and lesion of the central nervous system (CNS). Generally in all disabilities there is a loss of lean tissue mass (LM) and bone mineral density (BMD) vs. gain in fat mass (FM) in body composition. These changes have negative consequences to the disabled individuals Increased body fat is significant predictor of mortality while metabolic disorders are presented with increased frequency in disabled population [1-5].

In children with cerebral palsy (CP) body composition may be significantly compromised. Increased stretch reflexes and muscle tone, weakness of involved musculature, and severe limitation of movement reduce the capacity to perform normal movements creating ambulation barriers limiting physical activity. Reduced physical activity (and probably reduced energy expenditure) in MS need to be accompanied by a reduction in energy intake because it has been shown in other disabled subjects that otherwise body fat will increase [6]. The dependency on mobility devices, common in all disabilities, and the frequent periods of immobilization after multiple operative procedures contribute to the hypo-activity status of such children [7].

They may have an appropriate walking gait pattern but may also be unable to walk at all, bedridden etc. [8-10]. In children with locomotion impairments balance and the change of their movement pattern which is observed following an intervention Berg Balance Scale, BBS [11] the balance unit (Balance Sub-Scale) of Bruininks-Oseretsky Test of Motor Proficiency, BOTMP [12] and Timed Up and Go, TUG [13] constitute the most frequently applied control tests of the quantitative changes of balance. Berg Balance Scale (BBS), time up and go (TUG) and Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) are considered to be reliable and valid tests, able to objectively define the quantitative mutation of the balance of the child in test with CP [14].

Therefore, the purpose of this chapter was to review body composition i.e. bone-mineral density, bone mineral content, and bone-mineral-free lean and fat tissue mass alterations of ambulatory and non-ambulatory subjects and balance in cerebral palsy (CP) subjects.

Body Composition Measurements

Anthropometric and body composition measurements

To standardize or index physiological variables, such as resting metabolic rate and fat free mass (FFM) is usually used [4]. Skeletal muscle represents 50% of the non fat component in the total body [15,16] and exact quantification of the amount of skeletal muscle is important to assess nutritional status, disease risk, danger of illnesses, physical function, atrophic effects of aging, and muscle-wasting diseases [17,18].

Because muscle wasting is a common sign of cerebral palsy (CP), even in well nourished children, the validity of using muscle wasting as evidence or measurement of malnutrition in CP is in doubt. Studies found that the triceps, midthigh, and calf skinfold thicknesses of the affected side were greater than those of the no affected side among children with hemiplegic CP [19]. Useful information regarding fat provides triceps, subscapular skinfolds and arm-fat area [20]. Other studies support the concept that the validity of skinfold thickness as an assessment of limb fat storage is dependent on the preservation of limb muscles [21] and suggested good sensitivity and specificity of triceps skinfold thickness for predicting midupper arm fat area probably were attributable to good preservation of mid-upper arm muscles among children with CP [22].

In disabled children techniques for measuring skinfolds are well established and standardized [23] and equations are available for calculation of body fat from skin fold thickness [24] although unvalidated in this population, as are normative values for skinfold thickness [25,26].

Consequently, use of skinfold thickness as a measurement, especially for the affected limb, should be used with discretion in the assessment of children with CP, who tend to have muscle wasting. In cerebral palsy neither bioelectrical impedance analysis nor predictive equations for skinfold thickness generated from normal, able-bodied adults accurately determined percentage body fat [27]. Body mass index (BMI), triceps skinfold thickness, subscapular skinfold thickness, suprailiac skinfold thickness, and circumferences of the biceps, waist, forearm, and knee were all significantly correlated with percentage body fat [28].

The hydrodensitometric model was regarded as the "gold standard" for body composition assessment. This model partitions the body into two compartments of constant densities [fat mass: 0.9007 g/cm^3 and FFM: 1.100 g/cm^3] and assumes that the relative amounts of the FFM components [water, protein, protein, bone mineral (BM), and non-BM] are fixed [4]. Hydrodensitometry is clearly inappropriate for individuals who deviate from these fixed and/or assumed values (e.g., children, elderly, blacks, obese), and its application is, therefore, somewhat limited [29].

Bioelectrical impedance analysis (BIA) has been used to measure cerebral palsy subjects. However, the inclusion of weight in the BIA predictive equation may reduce its accuracy in determining change in lean body mass [30]. The inability of BIA to accurately predict percentage body fat in the sample may be related to several factors. In the BIA method where the impedance of a geometrical system (i.e., the human body) is dependent on the length of the conductor (height) and its configuration, it is almost impossible to measure accurately height in subjects with CP because of their muscle contractures. An over- or underestimation of height by 2.5 cm can result in a l.0-L error in the estimation of TBW, producing a small error in the estimation of percentage body fat (< 5%). The second major problem is body asymmetry which renders the assumption of a symmetrical configuration of the human body invalid in this case [27,31].

Isotope dilution measures the water compartment of the whole body rather than a single area assumed to mimic the composition of the whole body. Thus, the use of a stable isotope to measure body composition is ideal for people with CP because it is non-invasive, does not require the subject to remain still for the measurement, and is independent of height and body symmetry. However, the prohibitive cost of the isotopes and the need for a mass spectrometry facility and highly trained technicians make this method impractical for routine clinical use [27].

To determine whether bioelectrical impedance analysis and anthropometry can be used to determine body composition for clinical and research purposes in children with cerebral palsy 8 individuals (two female, mean age=10 years, mean gross motor function classification=4.6 [severe motor impairment]) recruited from an outpatient tertiary care setting underwent measurement of fat mass, fat-free mass, and percentage body fat using BIA, anthropometry (two and four skinfold equations), and dual-energy x-ray absorptiometry. Correlation were excellent for determination of fat-free mass for all methods (i.e., all were above 0.9) and moderate for determination of fat mass and percent body fat (range=0.4 to 0.8). Moreover, skinfolds were better predictors of percent body fat, while bioelectrical impedance was a better predictor for fat mass. On the contrary another study investigated the pattern of body composition in 136 subjects with spastic quadriplegic cerebral palsy, 2 to 12 years of age, by anthropometric measures, or by anthropometric and total body water (TBW) measures (n=28), compared with 39 control subjects. Body composition and nutritional status indicators were significantly reduced. Calculation of body fat from two skinfolds correlated best with measures of fat mass from TBW [26,32]. Magnetic resonance imaging (MRI) provides remarkably accurate estimates of skeletal muscle *in vivo* [16]. MRI and also quantitative computed tomography (QCT) have been validated in studies of human cadavers in the assessment of regional skeletal muscle [33]. Although, these devices have disadvantages of high radiation exposure and are expensive.

Dual-energy X-ray absorptiometry (DXA)

Recently, dual-energy X-ray absorptiometry (DXA) has gained acceptance as a reference method for body composition analysis [34,35]. Originally designed to determine bone density, DXA technology has subsequently been adopted for the assessment of whole body composition and offers estimation rapidly, non-invasively and with minimal radiation exposure [4,36]. Moreover, is well tolerated in subjects who would be unable to tolerate other body composition techniques, such as underwater weighing (hydro-densitometry) [37].

DXA software determines the bone mineral and soft tissue composition in different regions of the body being a three-compartment model that quantifies: (i) bone mineral density and content (BMD, BMC), (ii) fat mass (FM); and (iii) lean mass (LM), half of which is closely correlated with muscle mass and also yields regional as well as total body values for example in the arms, legs, and trunk) [38].

DXA analyzes differently the dense pixels in body composition. Soft tissue pixels are analyzed for two materials: fat and fat-free tissue

mass. Variations in the fat mass/fat free tissue mass composition of the soft tissue produce differences in the respective attenuation coefficients at both energy levels. The ratio at the two main energy peaks is automatically calculated of the X-ray attenuation providing separation of the soft tissue compartment into fat mass and fat-free tissue mass (lean mass) [39,40]. A bone-containing pixel is analyzed for "bone mass" (bone mineral content, BMC) and soft tissue as the two materials. Thus, the fat mass/fat free tissue mass of the soft tissue component of the bone pixels cannot be measured, but only estimated [41].

The important issue on this is the investigation of distribution of bone mineral, fat and mass throughout the body. These changes induce the risk for diseases such as diabetes, coronary heart disease, dyslipidaimias and osteoporosis [42-45]. There is a need to quantify the alterations in body composition to prevent these diseases and their complications. Studies also reported that bone density measurements at one site cannot usefully predict the bone density elsewhere [33] because different skeletal regions, even with similar quantities of trabecular or cortical bone, may respond variably in different physiopathological conditions [37].

In disabled conditions the accuracy of skeletal muscle measured by DXA may be compromised when muscle atrophy is present. A lower ratio of muscle to adipose-tissue free mass indicates a lower proportion of muscle in the fat-free soft tissue mass. Crossectional area of skeletal muscle in the thighs after SCI is extensively reduced [46]. If this is the case muscle mass would be overestimated by prediction models that assume that muscle represents all or a certain proportion of the fat-free soft tissue mass, i.e. in spinal cord injured subjects [16]. DXA technique has been used in assessment of SCI and appears to be tolerated well by this population [47-49].

Physiopathological Context in Cerebral Palsy

Bone mineralization in children with CP has been found lower (bone-mineral values for the total body and total proximal femur) than sex- and age-matched able bodied children. This is illustrated by the BMC Z–scores determined at each skeletal site. The factors that contribute to low bone mineralization include genetic, hormonal, and nutritional problems (especially calcium and vitamin D) and weight-bearing physical activity, oral-motor dysfunction and anticonvulsant medication [50]. Free fat mass (FFM) in cerebral palsy subjects was found significantly lower than that in a normal adolescent population. In 60% of the studied population body fat exceeded the 90th percentile for age, even if most of the CP children had a low height and weight for age. In female subjects anthropometric measurements were highly correlated with measures of body fatness. Measuring fat by 18O dilution a hydration factor of 0.73 was assumed for FFM. A possible increase in the hydration factor would diminish measured FFM meaning that body fat appears increased. Moreover muscle spasms and spasticity in CP subjects deplete body glycogen. If glycogen is reduced the intracellular water would be reduced and the ratio extracellular water/total body water would increase. The same could result with a loss of body cell mass or an increase in the hydration factor [28].

Balance Tests in Cerebral Palsy

The reliability of Timed Up and Go (TUG) test was studied in 176 able-bodied children of 3-9 years and 41 children with cerebral palsy, age of 3-19 years [51]. For the reliability control of TUG, the intra-class correlation coefficient (ICC) was calculated among the different attempts of the same measurement as well as among the different measurements. In able-bodied children the value of ICC among the different measurements and attempts of the same measurement was 0.83 and 0.89, respectively. One the other hand in children with cerebral palsy, the values of ICC among the different attempts of the same measurement was 0.99 (reliability of TUG wasn't controlled among the different measurements). Concerning Berg Balance Scale (BBS), the validity in 36 children with cerebral palsy, age of 8 to 12 years old vs. children without health problems as control group was studied. BBS and in parallel Gross Motor Function Classification System (GMFCS), the most valid evaluation instrument of children with cerebral palsy, were applied to all children. The authors found that BBS can be considered as valid for the evaluation of balance in children with cerebral palsy [52]. Nevertheless, the reliability of BBS in children with or without locomotion impairments or other health problems hasn't been controlled. The great stability of scores ($p<0.001$), in the same examined child, after the passage of a week, which is actually a short period of time to establish an objective change of his locomotive condition, substantiates the competence of tests to give steadily the same result in a patient with unchangeable movement condition (test–retest reliability). The above-mentioned results stand in line with the claims of those who planned the specific tests concerning reliability [11-13] as well as with relevant results of other researchers' which have been previously published [51,52]. Especially Williams et al. [52] found out for the control of reliability of TUG that for able-bodied children the value of ICC among the different attempts of the same measurement was 0.89, while among the different measurements was 0.83. Furthermore, they found that in children with cerebral palsy the values of ICC among the different attempts of the same measurement was 0.99 [51]. Regarding BOTMP by studying the reliability of the balance unit of BOTMP in 20 children without health problems, considered that only two from the eight tests of balance unit of BOTMP can be regarded as reliable (the monopedal support in floor with the main foot and the walking forward on a line). This statement agrees with the results of this research that BOTMP is inferior in reliability in comparison with the two other tests. This could lie in the fact that BOTMP serves mainly the discrimination from pathological to normal (discriminative index) and not the quantitative estimation of a movement condition or its change following a treatment (intervention) [53]. Due to the limited age range of the children that participated in research (6-14 years old), results can't be generalized in children of younger or older age [14].

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