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The objective of the present study was to investigate the growth and body composition of younger children with cerebral palsy, using anthropometric measures and bioelectrical impedance analysis (BIA). We also looked into the relative strength and consistency between different measurements in analyzing body composition. Thirty-nine patients, aged 3 to 13, with an established diagnosis of cerebral palsy, and age- and sex-matched control subjects, were recruited for this study. Distribution of height-by-age and weight-by-age percentiles differed significantly between the study and the control groups, whereby the subjects of cerebral palsy grew shorter and lighter than normal subjects. The body fat percentage was statistically higher and the lean body mass, basal metabolic rate (BMR) and total body water were statistically lower in the study group as compared to the normal subjects. There was favorable agreement between BMI, weight-for-length index and percent body fat as measured by BIA, although only the last measurement differed statistically between the two groups. Gross motor function and self-care capability correlated significantly with height- and weight-by-age percentiles, but not with the body fat percentage in the study group. BIA was proved to be a simple and sensitive method to estimate body composition and applicable for young children with cerebral palsy. (Tw J Phys Med Rehabil 2004; 32(2): 55 - 62)

Key words: body composition analysis, cerebral palsy, bioelectrical impedance analysis

INTRODUCTION

Cerebral palsy (CP) is a non-progressive clinical syndrome that occurs after damage to the motor areas of the immature brain, and results in a variety of motor deficits. Apart from their motor deficits, children with cerebral palsy frequently grow poorly in terms of height and weight. [1] Both nutritional and non-nutritional factors have been postulated to play roles in the growth failure of children with cerebral palsy. [2] Postulated mechanisms for nutritional factors include increased caloric needs owing to tone and posture abnormalities, difficulties in performing tasks, and inadequate caloric intake owing to the increased feeding time needed by children with poor oral function. [2-4] Children with hemiplegic CP always dem-

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onstrate asymmetrical growth of the bilateral limbs. The possible mechanisms for the non-nutritional factors that cause altered growth include brain malformation or injury that negatively affects growth, disuse, decreased blood flow to the affected limbs and sensory deficit. [1] Although children with severe CP have lower total energy requirements, dietary intake is likely to be grossly overestimated due to the increased feeding time they spent on each meal. [3,5] According to our previous observation (not published), around one third of parents who have children with CP did in fact overlook the problems of either malnutrition or overweight, as well as possibly associated complications arising in this population.

Furthermore, an accurate definition of nutritional status cannot be based only on height and weight. Body composition analysis enables a better understanding of the effects of genetic, nutritional, and physical activity factors on fat, muscle, and bone development. This provides valuable information on nutritional management of patients with acute and chronic illness. [6] The assessment of body composition has traditionally been based on the two-compartment model, in which the body has been divided into fat mass (FM) and fat-free mass (FFM). [6,7] Among the measurements used for body composition analysis, anthropometric measures and bioelectrical impedance analysis (BIA) remain the most popular methods because of their simplicity for clinical use. [3,6,7-11] Although several previously published articles have looked into the growth and body composition of patients with CP, [1,2,4,5,12-21] certain of them actually only focus on studying adolescents and adults with CP. Besides, none of them has tried to investigate the relative strength and the correlation between different measurements in analyzing body composition in this particular patient population.

The objective of the present study was to investigate the growth and body composition of younger children with CP, using anthropometric measures and bioelectrical impedance analysis. We also looked into the relative strength and the agreement between different measurements in analyzing body composition, as well as clinical factors, which might contribute to altered growth in this population.

MATERIALS AND METHODS

Patients with an established diagnosis of cerebral palsy, who were monitored regularly at the outpatient clinic of a tertiary medical center, were recruited for this study. Demographic data, including sex, age, and type of CP, topographical distribution, gross motor function, and self-care capability in daily living activities (ADL) were collected at baseline. Gross motor function was classified by the Gross Motor Function Classification System for Cerebral Palsy (GMFCS) into five levels, with level I being walks without restrictions; level II being walks without assistive devices but with limitations walking outdoors; level III being walks with assistive devices and limitations walking outdoors; level IV being self-mobility with limitations and are transported or use power mobility outdoors; and level V being severely limited in self-mobility even with the use of assistive technology. [22,23] Capability in self-care was classified into three levels with level I being completely independent in ADL, level II being partially dependent in ADL and level III being totally dependent. Age- and sex-matched control subjects from the community and schools, without any previous history of developmental anomalies or neurological deficits, were also enrolled for comparison. The Ethics Committee of the Veterans General Hospital approved this study. All of the parents and guardians gave their informed written consent before participation.

Study design

Anthropometric measurements consisted of body weight and length for the children with CP, or standing height for the control subjects. A measuring tape was used to measure the length of children with CP so as to minimize the influence of soft tissue contracture and/or muscle weakness on standing height measurement by one of the authors (P.H.L.). Using the height by age and weight by age percentiles for Taiwanese children, [11] we obtained the growth percentile for height and weight of each subject. [24]

We then calculated the weight-for-length index with the following formula: [9,10]

$$\text{Weight-for-length index} = \frac{\text{weight(kg)/height(cm)}}{\text{age- and gender-specific weight-for-length constant}}$$

where

$$\text{age- and gender-specific weight-for-length constant} = \frac{50^{th}\text{ percentile of weight}}{50^{th}\text{ percentile of height}}$$

The age- and gender-specific weight-for length constant used here was adopted from the data published by Chen et al. in 1999. [11] This index would yield information regarding each child's nutritional status for that particular age and gender group. The child was considered to be malnourished if the index was below 0.80; as underweight if the index ranged between 0.80 and 0.89; normal if the index ranged between 0.90 and 1.09; overweight if the index ranged between 1.10 and 1.19; and obese if the index was above 1.20.

Body mass index (BMI), a widely accepted index for classifying adiposity, was also calculated for each subject. [8,10] This was determined by dividing the person's weight in kilograms by their height in meters square. [22] The formula for BMI is:

$$\text{BMI} = \text{weight(kg)}/\text{height}^2\text{(meters)}$$

Age and gender-specific BMI reference data was only available for children of school age and older, but not for preschool age. A six years old Taiwanese boy would be regarded as underweight if BMI was below 13.9 and overweight if BMI above 17.9.

The bioelectric impedance analysis (BIA) for estimating body composition is noninvasive, rapid, inexpensive, portable, easy and applicable to field conditions. [6] The characteristics and composition of a material can be determined by analyzing their effect on an electrical current conducted in the material. The effect due to energy dissipation is called resistance. The effect due to energy storage is called reactance. Resistance and reactance taken together are called the impedance. Fat-free mass in the human body is proportional to the resistance. Body cell mass is proportional to the reactance. A bioimpedance analyzer measures resistance and reactance and computes fat-free mass, body cell mass, total body water, and intracellular water. The BIA 310 Bioimpedance Analyzer (BIA 310, Biodynamics Corporation, Seattle, WA, U.S.A.) used in the present study is a portable, battery-powered bioimpedance (BIA) analyzer. It has been used in a range of specific groups, including the elderly, children and adolescents. [7] The technique involves attaching adhesive surface electrodes to the middle parts on the dorsal surface of the hand and the ipsilateral foot of the subject, who lies flat on a nonconducting surface with legs abducted, preferably with the thighs not touching. Tests times last for only a few seconds and the raw output is transmitted to a host computer where dedicated software processes the data. The BIA outcome measures include percent body fat, lean body mass, basal metabolic rate (BMR) and total body water. Because there was no healthy percent body fat ranges available for children younger than 20, so we recruited a group of age-and gender-matched healthy subjects for comparison.

Statistical analysis

The chi-square test was used to analyze the distribution of ordinal scales between the study and control groups. The Mann-Whitney U test was used to investigate the difference in numerical scales between the two groups. We also used the Spearman's rho correlation to assess the correlation between the clinical factors and outcome measures of body composition. All statistical analyses were conducted with SPSSx software (SPSS, Inc., Chicago, IL, USA). A p value of less than 0.05 was considered to be statistically significant.

RESULTS

Twenty-one boys and eighteen girls aged 3 to 13, with cerebral palsy, were enrolled in this study. Their mean age was 5.4±2.1 years old. Thirty-nine age- and sex-matched normal subjects were also recruited from the community and schools for comparison. The distribution of disease type in the study group included 34 with spastic type, 2 with dyskinetic type and 3 with hypotonic type cerebral palsy. As to topographical distribution, 4 of the group were hemiplegic, 24 were diplegic and 11 were quadriplegic. Seven were classified by GMFCS as level II, 12 level III, 8 level IV and 12 level V. Five were independent in ADL, twenty-three were partially dependent and eleven were totally dependent in ADL. Three children in the study group were fed mainly through nasogastric tubes because of poor oral motor function and recurrent respiratory infections.

Distribution of height-by-age and weight-by-age percentiles differed significantly between the study and control groups, with a p value of <0.001 and equal to 0.015, respectively (see Table 1). However, the BMI and

Table 1. Distribution of height-by-age percentiles and weight-by-age percentiles for the study and control groups

Percentiles	CP		Control	
	Height (No.)	Weight (No.)	Height (No.)	Weight (No.)
≤ 10	25	16	2	7
10-25	7	12	7	6
25-50	4	6	8	8
50-75	2	1	9	9
75-90	1	2	8	5
≥ 90	0	2	5	4

P <0.001 and equal to 0.015 for height- and weight-by-age percentiles, respectively, by chi-square test.

the distribution of nutritional status, as classified by weight-for-length index, did not differ significantly between the two groups (see Table 2 and 3). Children with CP did grow significantly poorer, both in height and weight, but had a statistically higher percent body fat than normal subjects as well (see Table 3). The lean body mass, BMR and total body water were statistically lower in the study group as compared to the normal subjects.

BMI, weight-for-length index and percent body fat as measured by BIA were found to correlate significantly with each other, both in the study and control groups (see Table 4), although only body fat percentage did differ statistically between the two groups.

There was a significant correlation between clinical factors (gross motor function, and self-care capability) and height- and weight-by-age percentiles (see Table 5). However, these clinical factors did not correlate significantly with body fat percentages within the study group.

DISCUSSION

Children with severe disabilities, including CP, have a markedly increased risk of malnutrition. Chronic undernutrition, characterized by growth failure and reductions in fat and lean body mass, is the most common form of malnutrition, but overweight and obesity also occur. [3] Growth failure has been related to the type of CP and its topographical distribution. Oral-motor dysfunction has also been associated with poorer growth. [2,4] Sullivan et al. indicated the prevalence of feeding problems in children with neurological impairment, with 89 percent needing help with feeding and 56 percent choking on their food. [5] Twenty percent of parents described feeding as stressful and unenjoyable. Twenty-eight percent of parents reported prolonged feeding times (3 hour/day). In our series, children with CP did grow significantly poorer in both height and weight (Table 1 and 3), which was compatible with previous studies. Although the majority of CP children in our series (23/39) were classified as having a non-optimal nutritional status, according to the weight-for-length index, some of them had never had their feeding and nutritional status assessed before. Many of them would definitely benefit from nutritional assessment and management as part of their overall care.

Table 2. Distribution of nutritional status as classified by weight-for-length index for the study and control groups

Nutritional status	CP (No.)	Control (No.)
Malnutrition	9	5
Underweight	11	10
Normal	16	19
Overweight	1	1
Obesity	2	4

P = 0.715 by chi-square test

Although children with CP grew significantly lighter than normal controls, they did have a higher percent body fat as well as lower lean body mass, BMR and total body water. This observation again indicates that the accurate

Table 3. Difference of growth and body composition between the study and control groups

	CP	Control
Height (cm)*	103.64 ± 12.58	112.26 ± 13.14
Weight (kg)*	17.72 ± 6.48	20.21 ± 6.00
BMI	16.10 ± 2.91	15.76 ±2.22
Percent body fat (%)*	18.25 ± 6.90	13.94 ± 5.65
Lean body mass (kg)*	14.13 ± 5.05	17.20 ± 4.47
BMR (cal/day)*	434.74 ± 153.62	523.54 ± 135.71
Total body water (L)*	11.01 ± 3.60	13.16 ± 3.15

BMI = body mass index; BMR = basal metabolic rate.
*P<0.05 by Mann-Whitney U test

Table 4. Correlation of body composition measured by BMI, weight-for-length index and BIA

	CP			Control		
	BMI	WFL index	Body fat	BMI	WFL index	Body fat
BMI r	1.000	.858 *	.627 *	1.000	.866 *	.799 *
WFL index r		1.000	.654 *		1.000	.656 *
Body fat r			1.000			1.000

BMI = body mass index, WFL index = weight-for-length index, BIA = bioelectric impedance analysis,
r = correlation coefficient.
* Correlation is significant at the .01 level (2-tailed) by Spearman's rho correlation.

Table 5. Correlation of clinical factors and growth of height and weight in the study group

	height-by-age percentiles (r)	weight-by-age percentiles (r)
Gross motor function	-0.56*	0.88*
Self-care capability	-0.42*	-0.37*

r = correlation coefficient.
* Correlation is significant at the .05 level (2-tailed) by Spearman's rho correlation.

definition of nutritional status cannot be based only on height and weight. Body composition analysis would allow a better understanding of their nutritional status and would provide particularly valuable information in nutritional management of patients with CP. [6]

Samson-Fang et al. indicated that sex, age, cognitive impairment, ambulatory status and nutritional state are factors which may contribute to slow linear growth in children with CP. [14] Chad et al. also suggested that non-nutritional factors, such as ambulation, account for the low bone-mineral content, bone-mineral density and bone-mineral-free lean tissue observed in this population. [12] The limited sample size in the present study did prevent us from analyzing the effect of CP type and topographical distribution on growth. However, our series did observe that children with better functional status and milder involvement of CP did grow better, both in terms of height and weight, as expected (Table 5). Also, Ferrang et al. reported that adults with CP who participated in regular exercise programs had a significantly higher mean adequacy ratio and lower body fat percentages than those who did not exercise regularly. [16] However, functional status and disease severity, in the present study, did not correlate significantly with body fat percentage. Small sample size is one of the possible contributing factors. The other possible explanation is that energy expenditure for daily essential functions of younger children with CP was not equivalent to the energy expenditure for athletic participation of adults with CP. If younger children with CP could be engaged regularly in certain types of athletic activity, there would possibly be a positive impact on body composition as well.

In the present study, although there was a significant difference in height and weight between the study and control groups, the BMI and weight-for-length index did not differ so much in the meantime. Ferrang et al. also indicated that although 40% of their sample had heights below the 5th percentile for their age, the BMI of both men and women with CP were still within the normal range. [16] Given the fact that children with CP often grow poorer in both height and weight, it is not surprising that the effect of altered growth would probably be cancelled out in the formulas that these two outcome measures drew from. Although there are still some uncertainties regarding the precision and accuracy of the bioelectrical impedance method for estimating body composition, BIA continues to be used in research studies. It appears that under well-controlled conditions, with the use of adequate data and proper equations, the results can be valuable. [6] BMI, weight-for-length index and percent body fat measured by BIA are three methods used frequently to estimate body composition .[6-10,22] None of the previous studies had investigated the agreement between these measures. Although our findings suggested a significant correlation between the above three measures, only percent body fat measured by BIA could differentiate CP patients from normal children. This implied that besides being noninvasive, rapid, inexpensive and portable, [6,7] BIA is a more sensitive measure as compared to the other two methods in this particular patient population, and has proved to be applicable not only to adolescents and adults, but also to younger-aged children. A thorough body composition analysis by BIA is highly recommended for young children with CP so as to define their nutritional status accurately and see if further nutritional consultation and management are necessary.

CONCLUSION

Children with CP did grow significantly shorter and lighter and have a higher percent body fat as well as a lower lean body mass and BMR than normal children. BIA proved to be a simple method to estimate body composition, provide more valuable information regarding nutritional status than the other two measures and applicable to young children with CP.

REFERENCES

1. Stevenson RD, Roberts CD, Vogtle L. The effects of non-nutritional factors on growth in cerebral palsy. Dev Med Child Neurol 1995;37:124-30.
2. Shapiro BK, Green P, Krick J, et al. Growth of severely impaired children: neurological versus nutritional factors. Dev Med Child Neurol 1986;28:729-33.
3. Zemel BS, Stallings VA. Energy requirements and nutritional assessment in developmental disabilities. In: Walker WA, Watkins JB, editors. Nutrition in pediatrics. 2nd ed. London: B.C. Decker Inc. Publisher; 1997. p.169-77.
4. Rogers B, Andrus J, Msall ME, et al. Growth of preterm infants with cystic periventricular leukomalacia. Dev Med Child Neurol 1998;40:580-6.
5. Sullivan PB, Lambert B, Rose M, et al. Prevalence and severity of feeding and nutritional problems in children with neurological impairment: Oxford feeding study. Dev Med Child Neurol 2000;42:674-80.
6. Puig M. Body composition and growth. In: Walker WA, Watkins JB, editors. Nutrition in pediatrics. 2nd ed. London: B.C. Decker Inc. Publisher; 1997. p.44-62.
7. Brodie DA, Stewart AD. Body composition measurement: a hierarchy of methods. J Pediatr Endocrinol Metab 1999;12:801-16.

8. Dietz WH, Bellizzi MC. Introduction: the use of body mass index to assess obesity in children. Am J Clin Nutr 1999;70(1 part 2):S123-5.
9. Chen W, Wu KW, Mi LL, et al. Weight-for-length index in evaluation of children's body weight status: a simple and accurate method. J Formos Med Assoc 1993;92:S128-34.
10. 兒童肥胖之指標。國家衛生研究院論壇：兒童體位之評定及影響因素。台北：國家衛生研究院；2000。p.33-42。
11. Chen W, Jiang JS, Hwang BC. The revised growth curve in Taiwan area, 1997. J Central Formos Med Assoc 1999;4:256-63.
12. Chad KE, McKay HA, Zello GA, et al. Body composition in nutritionally adequate ambulatory and non-ambulatory children with cerebral palsy and a healthy reference group. Dev Med Child Neurol 2000;42:334-9.
13. Samson-Fang LJ, Stevenson RD. Identification of malnutrition in children with cerebral palsy: poor performance of weight-for-height centiles. Dev Med Child Neurol 2000;42:162-8.
14. Samson-Fang LJ, Stevenson RD. Linear growth velocity in children with cerebral palsy. Dev Med Child Neurol 1998;40:689-92.
15. Kong CK, Tse PW, Lee WY. Bone age and linear skeletal growth of children with cerebral palsy. Dev Med Child Neurol 1999;41:758-65.
16. Ferrang TM, Johnson RK, Ferrara MS. Dietary and anthropometric assessment of adults with cerebral palsy. J Am Diet Assoc 1992;92:1083-6.
17. Hildreth HG, Johnson RK, Goran MI, et al. Body composition in adults with cerebral palsy by dual-energy X-ray absorptiometry, bioelectrical impedance analysis, and skinfold anthropometry compared with the 18O isotope-dilution technique. Am J Clin Nutr 1997;66:1436-42.
18. Johnson RK, Hildreth HG, Contompasis SH, et al. Total energy expenditure in adults with cerebral palsy as assessed by doubly labeled water. J Am Diet Assoc 1997;97:966-70.
19. Johnson RK, Goran MI, Ferrara MS, et al. Athetosis increases resting metabolic rate in adults with cerebral palsy. J Am Diet Assoc 1996;96:145-8.
20. Bandini LG, Schoeller DA, Fukagawa NK, et al. Body composition and energy expenditure in adolescents with cerebral palsy or myelodysplasia. Pediatr Res 1991;29:70-7.
21. Azcue MP, Zello GA, Levy LD, et al. Energy expenditure and body composition in children with spastic quadriplegic cerebral palsy. J Pediatr 1996;129:870-6.
22. Palisano RJ, Hanna SE, Rosenbaum PL, et al. Validation of a model of gross motor function for children with cerebral palsy. Phys Ther 2000;80:974-85.
23. Wood E, Rosenbaum P. The gross motor function classification system for cerebral palsy: a study of reliability and stability over time. Dev Med Child Neurol 2000;42:292-6.
24. Hendrick KM. Nutritional assessment: anthropometrics and growth. In: Hendrick KM, Duggan C, Walker WA, editors. Manual of pediatric nutrition. 3rd ed. London: BC Decker; 2000. p.8-51.

腦性麻痺孩童體位及身體組成的分析

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本研究藉由體位及身體組成的分析來瞭解腦性麻痺患者與正常孩童在成長發育方面的異同，同時探討不同的身體組成分析方法之間的相關性以及效度。總共收集了 39 位 3 至 13 歲的腦性麻痺患者，並以 39 位性別、年齡相當的正常孩童爲對照組加以分析。結果發現腦性麻痺組的平均身高及體重，顯著低於對照組，但是腦性麻痺組體脂肪百分比顯著高於對照組，而瘦肉組織、水含量及基礎代謝率顯著低於對照組。臨床上身體重高指數、身體質量指數及生物電阻分析都是可行的體脂肪測量法，但是本研究發現雖然這三種測量法互相之間有不錯的相關性，但只有生物電阻分析法可鑑別出兩組在身體組成上的差異。腦性麻痺組中其臨床嚴重程度及行動能力與身高及體重的百分等級顯著相關，但與體脂肪百分比無關。本研究證實生物電阻分析法是一個簡單又敏感的身體組成分析法，並且適用於年幼的腦性麻痺孩童。（台灣復健醫誌 2004; 32(2): 55 - 62）

關鍵詞：身體組成分析(body composition analysis)，腦性麻痺(cerebral palsy)，
生物電阻分析法(bioelectrical impedance analysis)

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