Nutrición Hospitalaria

Original/*Pediatría*

Energy expenditure in children with cerebral palsy and moderate / severe malnutrition during nutritional recovery

Andrea A. García-Contreras[1], Edgar M. Vásquez-Garibay[1,2], Enrique Romero-Velarde[1,2], Ana I. Ibarra-Gutiérrez[2] and Rogelio Troyo-Sanromán[1]

[1]Instituto de Nutrición Humana. Universidad de Guadalajara. [2]Hospital Civil de Guadalajara Dr. Juan I. Menchaca, México.

Abstract

Objective: To analyze the total energy expenditure (TEE) and resting energy expenditure (REE) in children with cerebral palsy (CP) and moderate or severe malnutrition during nutritional recovery.

Methods: In an intervention study, thirteen subjects with CP (10 females and 3 males with a mean age of 9y11m ± 2y3m), level V of the Gross Motor Function Classification System and moderate or severe malnutrition were included. Eight were fed by nasogastric tube and five by gastrostomy. They were compared with 57 healthy participants (31 females and 26 males with mean age of 8y7m ± 10 m). Anthropometric measurements, body composition and energy expenditure by bioelectrical impedance analysis (BIA) and indirect calorimetry (IC) were performed in both groups.

Results: TEE and REE were higher in healthy children than in children with CP in kcal/d and kcal/cm/d but were lower in kcal/kg/d (p <0.001). Intensive nutritional support for four weeks in children with CP produced a significant increase in energy expenditure.

Conclusion: TEE and REE, in children with CP, are lower than in healthy children. Estimating the REE in children with CP and malnutrition is better performed in kcal/kg/d than in kcal/cm/d. Fat-free mass (FFM) is a good predictor of the REE in healthy children and children with CP.

(*Nutr Hosp*. 2015;31:2062-2069)

DOI:10.3305/nh.2015.31.5.8588

Key words: *Energy expenditure. Cerebral palsy. Malnutrition*

GASTO ENERGÉTICO EN NIÑOS CON PARÁLISIS CEREBRAL INFANTIL Y DESNUTRICIÓN MODERADA Y GRAVE DURANTE LA RECUPERACIÓN NUTRICIA

Resumen

Objetivo: Analizar el gasto energético total (GET) y gasto energético basal (GEB) en niños con parálisis cerebral infantil (PCI) y desnutrición moderada o grave durante la recuperación nutricia.

Métodos: En un estudio de intervención, se incluyeron trece sujetos con PCI (10 mujeres y 3 hombres, con una edad promedio de 9a11m±2a3m), pertenecían al nivel V del Sistema de Clasificación de la Función Motora Gruesa y desnutrición moderada o grave. Ocho fueron alimentados por sonda nasogástrica y cinco por gastrostomía. Se compararon con 57 participantes sanos (31 mujeres y 26 varones con una edad promedio de 8a7m±10m). Se realizaron mediciones antropométricas, de composición corporal y de gasto energético mediante el análisis de impedancia bio-eléctrica (IBE) y calorimetría indirecta (CI) en ambos grupos.

Resultados: El GET y GEB fueron mayores en los niños sanos que en los niños con parálisis cerebral en kcal/d y kcal/cm/d, pero fueron menores en kcal/kg/día (p <0,001). El apoyo nutricio intensivo durante cuatro semanas en los niños con parálisis cerebral produjo un incremento significativo en el gasto energético.

Conclusión: El GET y GEB en niños con parálisis cerebral, son más bajos que en los niños sanos. La estimación del GEB en niños con parálisis cerebral y desnutrición moderada y/o grave se realiza mejor en kcal/kg/d que en kcal/cm/d. La masa libre de grasa (MLG) es un buen predictor del GEB en niños sanos y en niños con parálisis cerebral.

(*Nutr Hosp*. 2015;31:2062-2069)

DOI:10.3305/nh.2015.31.5.8588

Palabras clave: *Gasto energético. Parálisis cerebral. Desnutrición*

List of abbreviations

BIA: Bioelectrical impedance analysis.
BMI: Body mass index.
CP: Cerebral palsy.
FFM: Fat-free mass.
H/A: Height/age.
IC: Indirect calorimetry.
MUAC: Medium upper arm circumference.
REE: Resting energy expenditure.
ROC: Receiver Operating Characteristic
SSF: Subscapular skinfold.
TEE: Total energy expenditure.
TSF: Triceps skinfold.
W/A: Weight/age.
W/H: Weight/height.
WHO: World health organization.

Introduction

The prevalence of malnutrition in children with cerebral palsy (CP) is high[1-4] and is commonly associated with feeding difficulties in 94.3% of cases. Symptoms of gastro-esophageal reflux in 81.1% of cases result in chronic poor energy intake[5].

It has been suggested that the resting energy expenditure (REE) is significantly lower in non-ambulatory patients with disabilities than in ambulatory patients [6].Additionally, it has been determined that both the REE and total energy expenditure (TEE) are significantly lower in children with cerebral palsy than in healthy children of similar age according to various methods: indirect calorimetry (IC), doubly labeled water and equations of the World Health Organization (WHO)[7-9].A reason why the REE is lower in children with CP is that these children have been fed with low energy diets over a prolonged period of time while adapting to this phenomenon; however, the REE can be normalized if children with CP receive adequate energy intake[5].Moreover, the estimation of energy intake in these children with the use of the 24 h dietary recall survey has limitations; energy intake can be overestimated by 193% compared with the REE estimated by indirect calorimetry[5].

Current studies advise against the use of equations for healthy children to estimate energy expenditure because children with CP differ in body composition, physical activity, growth and feeding habits from healthy children [5,8,9]. Azcue et al[8] estimated the energy requirements of children with CP, and they are, on average, 1.1 times the REE. However, the energy requirements for children with CP should be calculated from the estimated REE [10].

Energy requirements for tube-fed patients with neurological disabilities who are non-ambulatory (adolescents and adults) have been analyzed and compared with equations such as Harris-Benedict and FAO/ WHO/UNU[11]. However, in previous studies of children with CP, the REE differs significantly between children with low fat stores and children with adequate fat stores[9].

The REE of children with CP and moderate and/or severe malnutrition during nutritional recovery and the best way to estimate the REE in these children is unknown. Therefore, the aim of this study was to estimate the energy expenditure of children with CP during nutritional recovery by bioelectrical impedance and indirect calorimetry and to compare it with the REE and TEE of healthy children of the same age.

Methods

In an intervention study, 15 subjects (10 females and 5 males) with spastic quadriplegic CP, moderate or severe malnutrition, and non-ambulatory with severe brain damage were included. The age ranged from 6 years 9 months to 12 years 8 months (9y11m ± 2y3m). Patients were recruited at the Infant Nutrition Unit of the Dr. Juan I. Menchaca Civil Hospital and were hospitalized for four weeks of nutritional recovery. They were fed enterally (nasogastric tube or gastrostomy n = 8 n = 5) with a lactose-free infant formula (Nestlé®) supplemented with corn syrup to increase the energy density from 0.67 to 0.80 kcal/mL. The formula was placed in a bag with a capacity of 500 mL (Pisa®) and connected to the feeding tube (D-731 or 732, of Mexico Desvar SA). It was administered by a continuous infusion pump (Braun®). During the first two weeks, energy intake was 112 kcal/kg/d (12 kcal/cm/d) and was 115-116 kcal/kg/d (14 to 16 kcal/cm/d) for the following two weeks[12]. Throughout the study period, the formula covered 100% fluid requirements, energy, protein and other nutrients, and no other foods were offered. Beginning on the sixth day, elemental iron was added at a dose of 3 mg/kg/d.

The sample size of children with CP was described in a previous publication[13] in which a confidence level of 95% was estimated and a power of 0.8 was determined according to the average and variance of a medium upper arm circumference (MUAC) study by Stallings et al.[3] Patients were included if they had moderate or severe acute malnutrition according to weight/height index (W/H) of the Waterlow classification[14] in addition to two or more of the following criteria: triceps skinfold (TSF), subscapular skinfold (SSF), MUAC and/or body mass index (BMI) below -2 SD[15]. All patients with CP had been confined to a wheelchair and were totally dependent on their parents or legal caregivers to meet their daily needs; belonged to group V of the Gross Motor Function Classification System[16] and were evaluated by a pediatric neurologist who was in charge of the development of children during the intervention study. Most of the children were receiving at least two of the following anticonvulsants: phenobarbital, valproic

acid, phenytoin, lamotrigine, topiramate, carbamazepine and clonazepam.

Children who had genopathies, heart disease, hypothyroidism, or any other condition not related to cerebral palsy as well as CP of a postnatal origin and subjects with comorbid diagnoses (Down syndrome, autism, degenerative disorders and kidney disease) were not included. Two cases were excluded: one because of inaccurate data and the other due to excessive secretions that prevented the adjustment of fluids and energy. Anthropometric measurements and IC were performed at baseline, 15 days and 30 days during the study period. In the control group, 57 healthy subjects (31 females and 26 males) were evaluated, and their age ranged from 7 to 10 years (similar to children with CP). The sample was obtained from two private elementary schools in the city of Guadalajara. Informed consent of the parents or legal caregivers of all children were obtained. The study was approved by the ethics committee of the Dr. Juan I. Menchaca Civil Hospital.

Indirect calorimetry

All patients with CP fasted for approximately ten hours, and no drugs were administered for 12 hours. The IC was performed in a room at ambient temperature, and a mask that hermetically covered the nose and mouth was placed with a leash. The test lasted for approximately 10 minutes. In some cases, due to agitation or involuntary movements, a stable reading measurement could not be obtained, so the test was repeated up to three times. A Ree Vue (model 8100, Salt Lake City, Utah) appliance was used. In the control group, the IC was performed with all participants who fasted for ten hours using the same procedure as in children with CP.

Anthropometry

Weight, height, TSF, SSF and MUAC were measured. Weight in children with CP was taken with minimal clothing and a clean diaper. A SECA® scale (model 700, Hamburg, Germany) with an accuracy of 50 g was used. To measure weight, the child was first weighed with his/her parent or legal caregiver and then only the parent or legal caregiver was weighed, and finally, the difference between both weights was obtained. [17] In the control group, the weight was obtained with a TANITA scale (UM061 model, Arlington Heights, Illinois, USA) with the child standing without shoes or socks. In children with CP, height was estimated using the average of knee height and leg length according to the methods described by Stevenson[4] with a segmometer (Rosscraft SRL, Buenos Aires, Argentina).

In the control group, height was measured with a portable SECA stadiometer (model 214, Hamburg, Germany). It was performed with the participant standing without shoes, with their heels together and with their toes slightly apart and with their back as straight as possible; heels, buttocks, shoulders and head were touching the vertical surface of the stadiometer. The head remained in the Frankfurt plane. The arms hung freely to their sides with palms facing the thighs. The observer asked the participant to breathe deeply as the moving part of the stadiometer descended to touch the subject's head. The skinfolds were taken with a Lange (Cambridge, Maryland) caliper and were measured three times by each observer, and an average of the three measurements and the average of the values obtained by both observers were calculated. A 5 mm wide metal tape was used to measure MUAC. The MUAC, TSF, SSF and BMI were converted to a Z score and were compared with Frisancho reference[16] tables. In children with CP, measurements of skinfolds and MUAC were performed on the least affected side. All of the measurements were performed by two observers who were previously standardized.

Bioelectrical impedance analysis

The following variables were obtained using the IBE: TEE, REE, fat-free mass (FFM), fat mass in kilograms and percentage of healthy children and children with CP. Measurements by BIA (BODYSTAT QuadScan 4000, Isle of Man, British Isles and) were obtained after three hours of fasting. In children with CP, the subject was placed with a hospital gown and a clean diaper in the supine position. Their jewelry and metal accessories were removed; an electrode was placed at the wrist, and another was placed above the knuckles. On the foot, an electrode was placed at the medial and lateral malleolus and another above the toes. The measurement was obtained with the child as relaxed as possible for approximately one minute. The impedance level was set to 50 Ohms. In healthy children, it was performed in the same way with the school uniform.

Statistical analysis

Student's t test for independent samples and the Mann Whitney U test for comparison of the general characteristics and anthropometric variables with CP group vs group of healthy children and for comparing the same data among male vs. female participants in the control group were used. Additionally, a comparison of REE by BIA vs IC by sex and the REE obtained by BIA and IC in the healthy male vs female participants, and for the comparison of REE and TEE by both methods among healthy children vs children with CP during nutritional recovery.

Paired T Test for dependent samples and post hoc tests to compare the REE and TEE in children with CP during nutritional recovery were used. The Pearson correlation coefficients between the REE by BIA and by IC with anthropometric indicators in the healthy group and the group with CP were obtained. Using a ROC curve, the sensitivity and specificity of both methods in determining the REE were obtained. For statistical analysis, SPSS was used in version 20 (SPSS Inc., Chicago, IL, USA).

Ethical considerations

The protocol used was approved by the Bioethics Committee of Guadalajara's Civil Hospital. Adequate information was given to parents about the importance of this interventional study, and after the informed consent was signed, authorization was given to include each child in the study. The study complied with the principles of the Declaration of Helsinki adopted by the 18th World Medical Assembly, Helsinki, 1964 and amended by the 29th World Medical Assembly, 1975, the 35th World Medical Assembly, 1983, and the 41st World Medical Assembly, 1989.

Results

Thirteen CP patients and 57 healthy subjects (26 males, 31 girls) were evaluated. During nutritional recovery, fluid intake was 139.5, 144 and 145 mL/kg/d at baseline, 15 days and 30 days, respectively. Energy intake was 12, 14 and 16 kcal/cm/d and proteins levels were 2.22, 2.29 and 2.33 g/kg/d, respectively. Due to the size of the sample of children with CP, the sample was not stratified by sex.

Characteristics and resting energy expenditure in healthy subjects

Table I relates the characteristics and REE of healthy participants separated by sex; significant difference in waist circumference, W/H index and BMI (p <0.05) between male vs female participants were found. The BIA test and IC could not be performed in a healthy female because their parents did not accept it. In another healthy female, we could not obtain the measurement of IC due to technical problems. The REE estimated with IC in healthy children was significantly higher in male subjects, and according to BIA, there were no differences by sex. REE was significantly higher in females with BIA than with IC (p <0.001). In males, the average REE obtained by BIA and IC was similar, but the variability was greater by IC. There was a significant result in the REE obtained by IC and BIA in females (r = 0.588, p <0.001) but not in males.

Table I

Characteristics and resting energy expenditure in healthy participants, mean (SD)

Variable	Males n = 26	Females n = 31	p
Age (years, months)	8,9 (1,2)	8,6 (0,5)	NS
Weight (Kg)	32 (6.0)	29 (5.3)	NS
Height (cm)	133 (7.2)	132 (6.8)	NS
MUAC (cm)	19.1 (2.3)	18.5 (1.9)	NS
MUAC (Z)	-0.42 (1.0)	-0.60 (0.71)	NS
TSF (mm)	12.4 (5.1)	14.7 (5.4)	NS
TSF (Z)	0.65 (1.23)	0.46 (1.0)	NS
SSF (mm)	8.9 (4.4)	8.7 (4.2)	NS
SSF (Z)	0.69 (1.23)	0.14 (0.72)	NS
Waist (cm)	58.9 (5.8)	55 (4.4)	0.014
BMI (kg/m^2)	18.1 (2.4)	16.9 (2.2)	0.050
BMI (Z)	0.95 (1.15)	0.32 (0.95)	0.029
Height/Age (Z) *	0.21 (0.73)	0.36 (0.95)	NS
Weight/Height (Z) *	0.49 (1.17)	-0.02 (0.86)	0.047
Weight/Age (Z) *	0.72 (1.11)	0.44 (0.94)	NS
REE-BIA (kcal/d)	1217 (131)	1148 (131)∞	NS
REE-IC (kcal/d)	1216 (283)	977 (201)∞	0.001

MUAC: Medium upper arm circumference; TSF: Tricipital skinfold; SSF: Subscapular skinfold; BMI: Body mass index; REE-BIA: resting energy expenditure-Bioelectrical impedance analyses; REE-IC: resting energy expenditure-indirect calorimetry.
* Frisancho AR [10]
∞ n=29
REE-BIA vs REE-IC male p=N.S.
REE-BIA vs REE-IC female p<0.001

Body composition and anthropometric indicators of healthy subjects and subjects with CP

Table II shows the anthropometric indicators of healthy children and children with CP; the age was similar in both groups. However, there were significant differences between groups in body composition and anthropometric indices W/H, height/age (H/A) and weight/age (W/A), p <0.001.

Total energy expenditure and resting energy expenditure

Table III shows the estimated TEE by BIA and REE by IC and BIA in kcal/d, kcal/cm/d and kcal/kg/d in healthy children and children with CP during the nutritional recovery period (baseline, 15 days and 30 days). Using the BIA method, the resting energy

Table II
Body composition and indicators of the nutritional status in healthy participants and patients with It should say CP, mean (SD)

Variable	Patients with CP (Final stage) % n = 13	Healthy participants n = 57	p
Age (years, months)	9,11 (2,3)	8,7 (0,8)	N.S.
Weight (Kg)	14.6 (2.6)	30.5 (5.7)	<0.001
Height (cm)	106.9 (13.2)	132.2 (6.9)	<0.001
MUAC (cm)	13.2 (1.15)	18.8 (2.10)	<0.001
MUAC (Z)	-2.82 (0.41)	-0.51 (0.85)	<0.001
TSF (mm)	7.4 (2.68)	13.7 (5.67)	<0.001
TSF (Z)	-0.93 (0.45)	0.55 (1.11)	<0.001
SSF (mm)	6.4 (1.86)	8.7 (4.25)	0.003
SSF (Z)	-0.33 (0.45)	0.39 (1.01)	0.001
BMI (kg/m^2)	12 (0.9)	17.3 (2.3)	<0.001
BMI (Z)	-1.88 (0.32)	0.61 (1.08)	<0.001
Height/Age (Z)$^&$	-4.17 (1.60)	0.29 (0.85)	<0.001
Weight/Height (Z)$^&$	-2.19 (0.76)	0.21 (1.04)	<0.001
Weight/Age (Z)$^&$	-2.57 (0.43)	0.57 (1.02)	<0.001
Fat-BIA (%)	22.4 (11.8)†	34.0 (7.8)*	0.004
Fat mass (kg)	3.4 (1.8)†	10.7 (3.9)Ø	<0.001
FFM-BIA (kg)	11.5 (2.5)°	19.8 (3.1)*	<0.001

MUAC: Medium upper arm circumference; TSF: Tricipital skinfold; SSF: Subscapular skinfold; BMI: Body mass index; FAT-BIA: Fat-Bioelectrical impedance analyses; FFM-BIA: Fat free mass-Bioelectrical impedance analyses.
% After 30 days of nutritional recovery; & Frisancho AR [10].
†n=11; *n=56; ° n=12; Ø n=55

expenditure and total energy expenditure were higher in healthy children than in children with CP if expressed in kcal per day and per cm, but TEE and REE were lower in both cases if expressed per kg/d (p <0.001). The REE by IC was higher in healthy children than in children with CP at various stages if expressed in kcal/d (p <0.01). In kcal/cm/d, it was greater if compared with the baseline phase of children with CP (p <0.001), but there were no significant differences at 15 days and 30 days; however, in kcal/kg/d, the REE was significantly lower in healthy children than in children with CP at baseline, 15 days and 30 days (p <0.001). TEE and REE were analyzed by both methods in the group of children with CP among the three phases of nutritional recovery. TEE and REE by BIA showed significant differences in kilocalories per day, kcal/cm/d, and kcal/kg/d by comparing baseline vs 15 days, baseline stage vs 30 days and 15 days vs 30 days, respectively. Moreover,

REE by IC showed significant differences only in the comparison of baseline vs 15 days, and the baseline stage vs 30 days in kilocalories per day, kcal/cm/d, and kcal/kg/d.

Table IV presents the correlation coefficients of REE by BIA (CP group and healthy children) and IC (group of healthy children) with various anthropometric variables. In the CP group, no correlation was found using IC; however, in the group of healthy children, the variable that showed the best correlation was FFM (r = 0.610, p <0.001); whereas, BIA showed significant correlation with weight, MUAC, waist circumference, BMI and W/A index. In the group of healthy children, only the REE obtained by IC showed correlation with the REE obtained by BIA (r = 0.443, p <0.001). The anthropometric indicator that showed the best correlation in the group of healthy children and children with CP at all times was weight. Variables including age, weight and FFM were correlated with the REE by BIA in the group with CP during nutritional recovery. Energy intake in the CP group was always higher than the TEE at all stages of nutritional recovery (1.19, 1.33 and 1.41 at baseline, 15 days and 30 days, respectively). The TEE/REE ratio was higher in the group of healthy children than in the CP group (1.59 vs 1.40, p <0.001). The sensitivity and specificity of each method was analyzed for both groups. BIA was the method with the highest specificity (98.2%) and sensitivity (100%), whereas indirect calorimetry had good sensitivity (92.3%) and poor specificity (65.5%). The breakpoints were 949.5 kcal for BIA and 979.5 kcal for IC.

Discussion

As reported in other studies[5-9,18,19], we showed that energy expenditure in kcal/d in children with CP is lower than in healthy children. A possible reason is that healthy children have greater linear growth, higher fat mass and fat-free mass, better nutritional status and a high proportion of TEE/REE[5,9]. The main cause of this difference in REE could be the decreased FFM, poor energy intake and limited physical activity in children with CP compared with healthy children of similar age[9,20]. FFM represents 55% to 88% of REE[11], and both show good correlation in healthy children; however, studies have not shown a correlation[5] in children with CP. In our study, the correlation between FFM and REE was substantially significant, both in healthy children and children with CP at the various phases of nutritional recovery; these results agree with those reported by Dickerson[11] in adolescents and adults. In CP children, in addition to FFM, the weight was the variable that best correlated with the REE obtained by BIA but not by IC. It is likely that this lack of correlation between the FFM and REE obtained by IC in children with CP was due to greater variability than observed if BIA was used.

Total energy expenditure and resting energy expenditure in healthy participants and patients with It should say CP, mean (SD)

Variable	Healthy participants [n]	Patients with CP Stage of nutritional recovery		
		Baseline [n]	15 days [n]	30 days [n]
TEE-BIA (kcal/d)	1880 (249) [56]	1121 (109) [10] ‡	1162 (107) [10] ‡	1189 (105) [10] ‡
TEE-BIA (kcal/cm/d)	14.2 (1.5) [56]	10.51 (0.66) [10] ‡	10.88 (0.68) [10] ‡	11.14 (0.70) [10] ‡
TEE-BIA (kcal/kg/d)	62.4 (6.2) [56]	93.8 (11.9) [10] ‡	85.4 (10.2) [10] ‡	81.4 (8.9) [10] ‡
REE-BIA (kcal/d)	1182 (133) [56]	801 (78) [10] ‡	830 (76) [10] ‡	849 (75) [10] ‡
REE-BIA (kcal/cm/d)	8.9 (0.79) [56]	7.04 (0.44) [10] ‡	7.30 (0.42) [10] ‡	7.47 (0.40) [10] ‡
REE-BIA (kcal/kg/d)	39.3 (3.4) [56]	66.8 (8.5) [10] ‡	61.2 (7.4) [10] ‡	58.1 (6.8) [10] ‡
Relationship TEE/REE (BIA)	1.6 (0.09) [56]	1.4 (0.00) [10] ‡	1.4 (0.00) [11] ‡	1.4 (0.00) [12] ‡
REE-IC (kcal/d)	1090 (269) [55]	567 (135) [13] ‡	790 (254) [13] Δ	775 (169) [13] ‡
REE-IC (kcal/cm/d)	8.2 (1.85) [55]	5.18 (1.21) [12] ‡	7.23 (2.77) [12] Ø	7.02 (1.61) [12] Ø
REE-IC (kcal/kg/d)	36.2 (8.0) [55]	39.9 (11.0) [13] Ø	56.6 (23.9) [13] ‡	54.6 (14.1) [13] ‡

TEE: Total energy expenditure; BIA: Bioelectrical impedance analyses; REE: Resting energy expenditure; ID: indirect calorimetry
‡ Healthy Participants vs Patients with CP; baseline, 15 days and 30 days p<0.001
Δ Healthy Participants vs Patients with CP 15 days p<0.01
Ø Healthy Participants vs Patients with CP, baseline, 15 days and 30 days p= NS
CP group:
TEE-BIA (kcal/d): baseline vs 15 days and baseline vs 30 days p<0.001, 15 days vs 30 days p=0.001
TEE-BIA (kcal/cm/d): baseline vs 15 days and baseline vs 30 days p<0.001, 15 days vs 30 days p=0.002
TEE-BIA (kcal/kg/d): baseline vs 15 days and baseline vs 30 days p<0.001, 15 days vs 30 days p=0.006
REE-BIA (kcal/d, kcal/cm/d and kcal/kg/d): baseline vs 15 days, baseline vs 30 days p<0.001, 15 days vs 30 days p=0.001
REE-IC (kcal/d): baseline vs 15 days p=0.006, baseline vs 30 days p<0.001, 15 days vs 30 days p=NS.
REE-IC (kcal/cm/d): baseline vs 15 days p=0.017, baseline vs 30 days p=0.001, 15 days vs 30 days p=NS.
REE-ICI (kcal/kg/d): baseline vs 15 days p=0.012, baseline vs 30 days p<0.001, 15 days vs 30 days p=NS.

We have not found other studies that have explored the changes in the REE in children with CP and moderate and/or severe malnutrition during a nutritional recovery period. Our study showed significant changes in TEE and REE among the various phases of nutritional recovery (baseline, 15 days and 30 days) by both BIA and IC. This finding may mean that the REE and TEE are significantly altered in a relatively short time in relation to the intensive nutritional support and changes in body composition in children with CP during nutritional recovery. Stallings et al[9] show that TEE both in kcal/day and kcal/kg/d is higher in healthy children than in children with CP with adequate and low fat stores. In comparing the REE (kcal/d) in children with CP and low fat stores with healthy children, the REE was lower, but if it was expressed in kcal/kg/d, no significant difference was found. However, in our study, we found that the TEE and the REE in kcal/kg/d were significantly higher in children with CP than in healthy children. These results could be due to an altered body composition in children with CP [21,22] because they have lower body cell mass [6,8,23], and the energy expenditure is greater per unit of weight. It would therefore be more accurate to estimate the REE in kcal/kg/d than in kcal/cm/d in children with CP, as

the height or length is difficult to accurately estimate because they have scoliosis, spasticity, contractures or lack of cooperation[4]. Therefore, there is greater error in the estimation of REE and TEE if they are estimated by height.

There are additional methods to estimate the TEE in children with CP with models such as the Schofield[24] equation or equation reported by Rieken et al, [25] and the latter is based on total body water (in kilograms) obtained by BIA. However, these equations have not been tested in children with CP and moderate/severe malnutrition undergoing intensive nutritional support. Furthermore, it is noted that the energy intake-TEE relationship in children with CP in our study (1.19 - 1.41) was similar to that reported by Stallings et al. [9] (1.44 - 1.54). In our patients, energy intake was estimated between 112 and 116 kcal/kg/d to produce an adequate increase in weight in children with CP and moderate or severe malnutrition. Using this intake, we achieved an increase of 2,700 g in four weeks of nutritional recovery (30 days).

A limitation of our study is the small population of children with CP that we obtained. Nevertheless, all were at the same level of disability, socioeconomic status and type of CP (spastic quadriplegia).

| Variable | Healthy participants (n=55) | | | | Children with CP (REE-BIA) | | | | | |
| | REE-BIA | | REE-IC | | Baseline (n=9) | | 15 days (n=10) | | 30 days (n=11) | |
	r	P	r	P	r	P	r	P	r	P
Age (years)	0.306	0.022	0.390	0.003	0.941	<0.001	0.862	<0.001	0.896	<0.001
Weight (kg)	0.948	<0.001	0.430	<0.001	0.898	<0.001	0.860	<0.001	0.943	<0.001
MUAC (cm)	0.858	<0.001	0.287	0.033	----	NS	----	NS	----	NS
SSF (mm)	0.715	<0.001	----	NS	----	NS	----	NS	----	NS
TSF (mm)	0.680	<0.001	----	NS	0.684	0.029	----	NS	----	NS
Waist (cm)	0.845	<0.001	0.364	0.003	----	NS	----	NS	----	NS
BMI (kg/m^2)	0.840	<0.001	----	NS	----	NS	----	NS	----	NS
Fat-BIA (%)	0.584	<0.001	----	NS	----	NS	----	NS	----	NS
Fat mass-BIA (kg)	0.869	<0.001	----	NS	----	NS	----	NS	----	NS
FFM–BIA (kg)	0.702	<0.001	0.610	<0.001	0.773	0.009	0.641	0.034	0.748	0.005
Weight/Height (%)	0.699	<0.001	----	NS	----	NS	----	NS	----	NS
Height/Age (%)	0.527	<0.001	0.266	0.049	----	NS	----	NS	----	NS
Weight/Age (%)	0.836	<0.001	----	NS	----	NS	----	NS	----	NS
Indirect calorimetry (kcal/d)	0.443	0.001	----	----	----	NS	----	NS	----	NS
Indirect calorimetry (kcal/cm/d)	0.275	0.042	----	----	----	NS	----	NS	----	NS
Indirect calorimetry (kcal/kg/d)	0.303	0.025	----	----	----	NS	----	NS	----	NS

REE-BIA: resting energy expenditure-Bioelectrical impedance analyses; REE-IC: resting energy expenditure-indirect calorimetry. MUAC: Medium upper arm circumference; SSF: Subscapular skinfold; TSF: Tricipital skinfold; BMI: Body mass index; Fat-BIA: Fat-Bioelectrical impedance analyses; Fat mass: Fat-Bioelectrical impedance analyses; FFM-BIA: fat free mass-Bioelectrical impedance analyses; REE-BIA: resting energy expenditure-Bioelectrical impedance analyses; REE-IC: resting energy expenditure-indirect calorimetry.

In conclusion, the REE and TEE were lower in children with CP and moderate/severe malnutrition than in healthy children of the same age. In contrast, if the REE and TEE were estimated in kcal/kg/d, they were significantly higher in children with CP than in healthy children. The variables that best correlated with the REE in children with CP were weight and FFM and were weight, FFM and MUAC in healthy children. The estimation of the REE in children with CP and moderate/severe malnutrition was best performed in kcal/kg/d ($\approx$ 56.7 kcal/kg/d) or by making adjustments to the changes in weight during nutritional recovery.

TEE was 1.4 times REE, which was higher than recommended by Azcue et al[8] (1.1 times the REE) and higher than the finding by Stallings[9] (1.29 in children with low fat stores and 1.07 in children with adequate fat stores). This finding was most likely because our population consisted of children with moderate or severe malnutrition. The BIA and IC are excellent methods to estimate the REE in healthy children given its good sensitivity; however, in children with CP, specificity was better by BIA than by IC.

Caution is advised with the use of IC to estimate the REE in children with CP and severe malnutrition because in the initial phase of nutritional recovery, a child's breathing is weak. Therefore, the oxygen consumed is difficult to detect, which is necessary for the use of this technique, leading to errors in measurement. According to the greater variability in the REE with IC in both healthy children and children with CP, the BIA method may be more accurate for estimation. Because the energy expenditure of children with CP and moderate/severe malnutrition differs significantly from the energy expenditure of healthy children, we believe that estimating energy expenditure by specific equations for healthy children is limited, and instead, methods such as BIA or IC are required to estimate it correctly.

jara Civil Hospital. We also thank the director of the Institute of Instituto de la Vera-Cruz and director of Altamira Elementary School for allowing us to assess children in these institutions.

Authors' contributions

Conceived and designed the experiments: AAGC, EVG. Performed the experiments: AAGC, EVG, AIIG. Analyzed data: AAGC, EVG, RTS. Wrote the paper: EVG, AAGC, ERV. All authors read and approved the final manuscript.

Competing interests

The authors have declared that no competing interests exist.

References

1. Spender QW, Cronk CE, Charney EB, Stallings VA. Assessment of linear growth in children with cerebral palsy: use of alternative measures to height or length. *Dev Med Child Neurol* 1989; 31:206-14.
2. Patrick J, Boland M, Stoski D, Murray GE. Rapid correction of wasting in children with cerebral palsy. *Dev Med Child Neurol* 1986; 28:734-9.
3. Stallings VA. Nutritional status and growth of children with diplegic or hemiplegic cerebral palsy. *Dev Med Child Neurol* 1993; 35:997-1006.
4. Stevenson RD. Use of segmental measures to estimate stature in children with cerebral palsy. *Arch Pediatr Adolesc Med* 1995; 149: 658-62.
5. Arrowsmith FE, et al. Nutritional rehabilitation increases the resting energy expenditure of malnourished children with severe cerebral palsy. *Dev Med Child Neurol* 2012; 54:170-5.
6. Bandini LG, Schoeller DA, Fukagawa NK, Wykes LJ, Dietz WH. Body composition and energy expenditure in adolescents with cerebral palsy or myelodysplasia. *Pediatr Res* 1991; 29:70-7.
7. Sert C, Atlindag O, Sirmatel F. Determination of basal metabolic rate and boy composition with bioelectrical impedance method in children with cerebral palsy. *J Child Neurol* 2009; 24:237-40.
8. Azcue M, Zello GA, Levy LD, Pencharz PB. Energy expenditure and body composition in children with spastic quadraplegic cerebral palsy. *J Pediatr* 1996; 129: 870-6.
9. Stallings VA, Zemel BS, Davies JC, Cronk CE, Charney EB. Energy expenditure of children and adolescents with severe disabilities: a cerebral palsy model. *Am J Clin Nutr* 1996; 64:627-34.
10. Krick J, Murphy PE, Markham JF, Shapiro BK. A proposed formula for calculating energy needs of children with cerebral palsy. *Dev Med Child Neurol* 1992; 34:481-7.
11. Dickerson RN, Brown RO, Gervasio JG, Hak EB, Hak LJ, Williams JE. Measured energy expenditure of tube-fed patients with severe neuro-developmental disabilities. *J Am Coll Nutr* 1999; 18:61-8.
12. Marchand V, Motil KJ. NASPGHAN Committee on Nutrition. Nutrtion support for neurologically impaired children: a clinical report of the North American Society for Pediatric Gastroenterology, Hepatology and Nutrition. *J Pediatr Gastroenterol Nutr* 2006; 43: 123-35.
13. García Contreras AA, Vásquez-Garibay EM, Romero-Velarde E, Ibarra-Gutiérrez AI, Troyo-Sanromán R, Sandoval-Montes IE. Intensive nutritional support improves the nutritional status and body composition in severely malnourished children with cerebral palsy. *Nutr Hosp*. 2014; 29: 838-43.
14. Waterlow JC. Classification and definition of protein-calorie malnutrition. *Brit Med J* 1972; 3:566-9.
15. Frisancho, AR. Anthropometric Standard for the assessment of growth and nutritional status. Ann Arbor, MI: *University of Michigan Press*, 1990.
16. Palisano R, Rosenbaum P, Walter S, Russel D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol* 1997; 39:214-23.
17. Arrowsmith F, Allen J, Gaskin K, Somerville H, Clarke S, O´Loughlin E. The effect of gastrostomy tube feeding on body protein and bone mineralization in children with quadriplegic cerebal palsy. *Dev Med Child Neurol* 2010; 52:1043-7.
18. Bandini LG, Puelzi-Quinn H, Morelli JA, Fukagawa NK. Estimation of energy requirements in persons with severe central nervous system impairment. *J Pediatr* 1995; 126: 828-32.
19. Fried M, Pencharz PB. Energy and nutrient intakes of children with spastic quadriplegia. *J Pediatr* 1991; 119: 947-9.
20. Bergqvist AG, Trabulsi J, Schall JI, Stallings VA. Growth failure in children with intractable epllilepsy is not due to increased resting energy expenditure. *Dev Med Child Neurol* 2008; 50:439-44.
21. Sullivan PB, Lambert B, Rose M, Ford-Adams M, Johnson A, Griffiths P. Prevalence and severity of feeding and nutritional problems in children with neurological impairment: Oxford Feeding Study. *Dev Med Child Neurol* 2000; 42:674-680.
22. van den Berg-Emons RJ, van Baak MA, Westertep KR. Are skinfold measurements suitable to compare body fat between children with spastic cerebral palsy and healthy controls? *Dev Med Child Neurol* 1998; 40:335-9.
23. Berg K, Isaksson B. Body composition and nutrition of school children with cerebral palsy. *Acta Pediatr Scand Suppl* 1970; 204:41.
24. Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr* 1985; 39(suppl 1):5-41.
25. Rieken R, van Goudoever JB, Schierbeek H, Willemsen SP, Calis EA, Tibboel D, Evenhuis HM, Penning C. Measuring body composition and energy expenditure in children with severe neurologic impairment and intellectual disability. *Am J Clin Nutr* 2011; 94: 759-66