



Original / *Pediatría*

## Intensive nutritional support improves the nutritional status and body composition in severely malnourished children with cerebral palsy

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### Abstract

**Objective:** To demonstrate that a nutritional support intervention, via naso-enteral tube-feeding or gastrostomy, has a significant impact on the nutritional status and body composition in severely malnourished children with cerebral palsy spastic quadriplegia

**Methods:** Thirteen patients with moderate/severe malnutrition and cerebral palsy spastic quadriplegia who were fed via naso-enteral tube-feeding or gastrostomy were included in a cohort study. Anthropometric measurements and estimated body composition by bioelectric impedance analysis were obtained. ANOVA and Wilcoxon tests were used.

**Results:** During the four weeks of nutritional recovery, an average weight increase of 2700 g was achieved. There were significant increases in anthropometric indicators, including BMI and weight/length ( $p < 0.01$ ). The increase in arm fat area was significantly higher than the increase in arm muscle area (104.5 vs 17.5%).

**Conclusion:** Intensive nutritional support for four weeks had a significant effect on the nutritional status and body composition of severe and moderately malnourished children with cerebral palsy spastic quadriplegia.

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Key words: *Severe malnutrition. Body composition. Cerebral palsy. Nutritional recovery.*

### EL APOYO NUTRICIO INTENSIVO MEJORA EL ESTADO NUTRICIO Y LA COMPOSICIÓN CORPORAL EN NIÑOS GRAVEMENTE DESNUTRIDOS CON PARÁLISIS CEREBRAL

### Resumen

**Objetivo:** Demostrar que el apoyo nutricio intensivo por vía naso-enteral o gastrostomía tiene un impacto significativo en el estado nutricio y en la composición corporal en niños desnutridos graves con parálisis cerebral cuadrupleja espástica.

**Métodos:** En un estudio de cohorte se incluyeron trece pacientes con desnutrición moderada/grave y parálisis cerebral cuadrupleja espástica, quienes fueron alimentados por vía naso-enteral o gastrostomía. Fueron obtenidos indicadores antropométricos y de composición corporal estimada por antropometría e impedancia bio-eléctrica. Se utilizó ANOVA y prueba de Wilcoxon para el análisis estadístico.

**Resultados:** Hubo un aumento de 2700 g durante las cuatro semanas de recuperación nutricia y un incremento significativo en los indicadores antropométricos, índice de masa corporal y peso/talla ( $p < 0,01$ ). El porcentaje de incremento del área grasa del brazo fue mayor que el área muscular del brazo (104,5 vs 17,5%).

**Conclusión:** El apoyo nutricio intensivo tuvo un efecto significativo en el estado nutricio y en la composición corporal de niños con desnutrición moderada/grave con parálisis cerebral infantil.

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Palabras clave: *Desnutrición grave. Composición corporal. Parálisis cerebral. Recuperación nutricia.*

### Non-conventional abbreviations

AMA: Arm muscle area.

AFA: Arm fat area.

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BCM: Body cell mass.

BIA: Bioelectric impedance analysis.

BMI: Body mass index.

CC: Calf circumference.

CP: Cerebral palsy.

CSF: Calf skin fold thickness.

DXA: Double-energy X-ray absorptiometry.

EBW: Extracellular body water.

EE: Energy expenditure.

FM: Fat mass.

FFM: Fat free mass.

IBW: Intracellular body water.

Lt: Liter.  
MUAC: Mid-Upper Arm Circumferences.  
PA: Phase angle.  
PEM: Protein energy malnutrition.  
TBW: Total body water.  
TC: Thigh circumference.  
TSF: tricipital skinfold.  
SSSF: Subscapular skinfold.  
THSF: thigh skinfold.  
WL: Weight for length index.

## Introduction

The neurological damage of cerebral palsy (CP) has a significant impact on body composition and nutritional status<sup>1</sup>, and these alterations are worse in children with a higher degree of motor impairment, primarily due to energy deficits. Because CP is accompanied by alterations in muscle strength, growth and body composition<sup>1,2</sup>, correct assessment of the nutritional status of children with CP is a real challenge<sup>3</sup>. The fat free mass (FFM) is lower in children with CP than in healthy children<sup>4,6</sup>. When malnutrition and CP coincide, it is important to consider the alterations in body composition that these children exhibit. In such cases, the fat stores and FFM<sup>4,7</sup> are severely depleted.

Some authors<sup>8</sup>, have noted that anthropometry and bioelectrical impedance analysis used for the evaluation of body composition are reliable and precise even in children who are severely affected by CP. Anthropometric methods correlate as closely as bioelectric impedance analysis (BIA) when they were compared to Double-energy X-ray absorptiometry (DXA) measurements for FFM and fat mass (FM)<sup>8</sup>.

Although enteral feeding (via a naso-gastric or gastrostomy tube) is a commonly used method in children with CP<sup>9</sup>, there are few studies that explore the changes in the body composition of children with CP and severe protein energy malnutrition (PEM) during the nutritional recovery period.

## Objective

To demonstrate that interventional nutritional support, via naso-enteral tube-feeding or gastrostomy, has a significant impact on the nutritional status and body composition in children with CP spastic quadriplegia and moderate or severe PEM.

## Methods

### Design

Between 2010 and 2011, 15 Mexican children with spastic quadriplegia CP (10 females and five males) with an age range from 6.9 to 12.8 years (a mean of 9.6 years)

were included in a cohort study and hospitalized for a four-week-period in the Infant Nutritional Unit of the Hospital Civil de Guadalajara "Dr. Juan I. Menchaca".

All participants were confined to a wheel-chair and were totally dependent on their parents or legal guardians for their daily needs. All were diagnosed at level 5 of the Gross Motor Function Classification for cerebral palsy according to a certified pediatric neurologist, who also completed the clinical evolution of the participants during the entire study period and prescribed antiepileptic treatment when necessary. Most of the participants were receiving at least two of the following antiepileptic drugs: phenobarbital, valproic acid, phenytoin, lamotrigine, topiramate, carbamazepine and clonazepam.

For ethical reasons, a non-random design with the subject as his own control was selected. Those with moderate or severe PEM based on a weight/length index according to the Waterlow classification<sup>10</sup> plus two or more of the following criteria were included: -2 SD tricipital and sub-scapular skin fold or body mass index (BMI) and Mid-Upper Arm Circumferences (MUAC)<sup>11</sup>. Children presenting genopathies, cardiopathies, hypothyroidism, or any pathology not related to CP were excluded. Patients with CP of postnatal origin (traumatic brain injury, near drowning, motor vehicle accident, brain tumor, and other acquired injuries) as well as patients with other concomitant diagnoses (autism, Down syndrome, degenerative disorders, renal disease) were not considered. Two cases were not included, one because of inadequate data, and the other because an excess of secretions impeded the readjustment of oral liquids and energy intake. Anthropometric measurements and BIA were obtained at the beginning, at 15 and at 30 days during the study period.

### Variables

Dependent variables: direct anthropometric indicators included: weight, length, Mid-Upper Arm Circumferences (MUAC), tricipital, sub-scapular, thigh and calf skin fold; indirect anthropometric indicators included: arm total area (ATA), arm muscle area (AMA) and arm fat area (AFA) with the following equations:  $AMA = [MUAC - (TSF \text{ cm} \times \pi)]^2 / 4 \pi$ ,  $AFA = ATA - AMA$ <sup>11</sup>. Weight/Length (W/L) indices and BMI were obtained. W/L index was compared with Krick et al. reference charts<sup>2</sup> and the BMI in the Z score with the Frisancho reference pattern<sup>11</sup>. Independent variables included: Gender, type of feeding and energy intake (kcal/cm/d).

### Anthropometric measurements

Before starting the study, two observers obtained measurements to standardize the anthropometric measurements. Weight was measured using a precision scale

of 50 g (SECA®, model 700, Hamburg, Germany) with the children without clothes but wearing just a clean diaper. First, the parent or legal guardian was weighed with the child in his or her arms, next, the parent or legal guardian was weighed, and the difference between the two weights was calculated to obtain the weight of the child<sup>5</sup>. The child's height was estimated by calculating the mean value obtained through equations; knee height and tibial length were measured according to described methods<sup>12</sup> using a segmometer (Rosscraft S.R.L., Buenos Aires, Argentina). MUAC, thigh circumference (TC) and calf circumference (CC) measurements were obtained with a 5 mm wide metallic anthropometric tape. The tricipital (TSF), sub scapular (SSSF), thigh (THSF) and calf (CSF) skin fold thickness were measured using a Lange skin fold Caliper (Cambridge, Maryland, EUA). All measurements were obtained using standard procedures. Two observers obtained the skin fold thickness measurements from the less impaired upper limb; each observer took three measurements, the mean was found, and then the two observers' means were calculated. Anthropometric measurements and indices were taken in the first 24 hours after admission and then at 15 and 30 days of the hospitalization period.

The TSF and SSSF were converted to Z score values and then compared with the Frisancho reference tables<sup>11</sup>. The percentage of body fat was calculated from the two Slaughter equations<sup>13</sup>. One equation used the TSF and SSSF ( $\Sigma$  TSF + SSSF < 35 mm): (for males) % fat = 1.21 ( $\Sigma$ TSF + SSSF) - 0.008 ( $\Sigma$ TSF + SSSF)<sup>2</sup> - 1.7; (for females) % fat = 1.33 ( $\Sigma$ TSF + SSSF) - 0.013 ( $\Sigma$ TSF + SSSF)<sup>2</sup> - 2.5. The other equation used the TSF and CSF: (for males) % fat = 0.735 ( $\Sigma$ TSF + CSF) + 1.0; (for females) % fat = 0.610 ( $\Sigma$ TSF + CSF) + 5.1.

### *Bioelectrical Impedance analysis*

BIA Measurements (BodyStat QuadScan 4000, Isle of Man, and British isles) were obtained after of three hours of fasting. Wearing only a small and light hospital gown and diaper, the patient was placed in a supine position, and any jewelry and metal accessories were removed; one electrode was attached at the level of the ulnar head at the wrist and the other just behind the knuckles. On the foot, the two electrodes were attached at the level of the medial and lateral malleoli and just behind the toes, respectively, and the measurements were taken with the child as relaxed as possible, taking about one minute in total. The impedance level was set to 50 Ohms. The percentages of FM and FFM were obtained as well and compared with those found via anthropometric measurements.

### *Criterion and strategies of clinical work*

Enteral feeding: eight children were fed via a naso-enteral tube and five through gastrostomy during a

four-week-period. As usual, in our nutritional support protocol for children hospitalized in this clinical context of children with severe PEM, non-lactose starting infant formula was used (Nestlé®). This formula has been routinely used because the relatively low protein content and the rest of nutrients are adequate for children with severe PEM. Corn syrup was added to the formula to increase the energy density from 0.67 to 0.80 kcal/mL. The formula was placed in a 500 mL feeding bag (Pisa®), introduced into a feeding tube (D-731 o 732, Desvar de Mexico, S.A.) and administered to the children using a continuous infusion pump (Braun®). During the first two weeks, the energy intake was 112 kcal/kg/d (12 kcal/cm/d) and it was 115 to 116 kcal/kg/d (14 to 16 kcal/cm/d) during the second two weeks. During this four-week period, the formula fulfilled the total requirements for water, energy, proteins and other nutrients, and no other foods were offered. From the sixth day on, elemental iron was given in daily doses of 3 mg/kg/d.

### *Statistical analysis*

To evaluate changes among quantitative variables during the study's three stages (initial, 15 and 30 days), an ANOVA for repeated measures and Friedman and Wilcoxon tests were used. To evaluate the differences between independent variables in the same stage of the recovery period, non-paired Student's T test was utilized; however, when those variables were without normal distribution, a Mann-Whitney U test was used. The SPSS program was used to analyze data (version 18, SPSS Inc., Chicago, IL, USA). The null hypothesis was rejected with a p value <0.05.

### **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.

### **Results**

A total of 13 participants (10 females and three males) with a mean age of  $9.7 \pm 2.2$  years completed the study. Enteral feeding was managed via a naso-gastric tube (n = 8) and gastrostomy (n = 5). At the initial, 15 and 30 day time-points, the total amount of formula for enteral feeding was 139.5, 144 and 145 mL/kg/d, respectively, the energy intake was 112 kcal/kg/d, 115 kcal/kg and 116 kcal/kg/d (12, 14, and 16 kcal/kg/cm), respectively, and the protein intake was 2.22, 2.29, and 2.33 g/kg/d, respectively. Weight, skin fold and cir-

cumference measurements showed significant increases at different stages during nutritional recovery, table I. TSF was affected more than SSSF, although both skin folds showed similar increases. The TSF and THSF skin fold thickness presented major increases (85%),

and TC had a high circumference recovery (20%). AFA showed a greater increase than AMA, 104.5% vs 17.5%, respectively. BMI and W/L also showed significant changes during the study period, table II. Table III shows FM and FFM indicators. The percentage values

**Table I**  
*Weight, skin folds and circumferences in the three stages during the nutritional recovery period (n = 13)*

Indicator	Initial Mean ± SD	Initial vs 15 d p value	15 days Mean ± SD	15 d vs 30 d p value	30 days Mean ± SD	Initial vs 30 d p value
Weight (Kg)	11.9 ± 2.3	‡	13.5 ± 2.7	‡	14.6 ± 2.6	‡
MUAC (cm)	11.2 ± 1.0	‡	12.4 ± 1.1	†	13.2 ± 1.2	‡
MUAC (Z)	-3.5 ± 0.3	‡	-3.1 ± 0.4	†	-2.8 ± 0.4	‡
TC (cm)	17.7 ± 3.0	‡	19.6 ± 2.3	†	21.2 ± 2.9	‡
CC (cm)	13.1 ± 1.7	‡	14.0 ± 1.4	†	14.8 ± 1.5	‡
TSF (mm)	4.0 ± 1.8	‡	5.5 ± 2.3	†	7.4 ± 2.7	‡
TSF (Z)	-1.6 ± 0.3	‡	-1.3 ± 0.4	†	-0.9 ± 0.4	‡
SSSF (mm)	3.7 ± 0.5	†	4.9 ± 1.3	†	6.4 ± 1.9	‡
SSSF (Z)	-0.8 ± 0.1	†	-0.6 ± 0.2	*	-0.3 ± 0.5	†
THSF (mm)	7.3 ± 5.3	†	10.2 ± 5.8	*	13.5 ± 7.7	†
CSF (mm)	5.8 ± 3.4	†	7.3 ± 4.0	†	9.4 ± 4.9	†

TSF: tricipital skin fold; SSSF: sub-scapular skin fold; THSF: thigh skin fold; CSF: calf skin fold; MUAC: Mid-Upper Arm Circumference; TC thigh circumference; CC: calf circumference. \* p < 0.05; † p < 0.01; ‡ p < 0.001.

**Table II**  
*Indirect anthropometric indicators in the three stages of the nutritional recovery period (n = 13)*

Indicator	Initial Mean ± SD	Initial vs 15 d p value	15 days Mean ± SD	15 d vs 30 d p value	30 days Mean ± SD	Initial vs 30 d p value
BMI (Kg/m <sup>2</sup> )	10.0 ± 1.0	‡	11 ± 0.8	†	12 ± 0.9	‡
BMI <sup>a</sup> (Z)	-2.8 ± 0.5	‡	-2.2 ± 0.3	†	-1.9 ± 0.3	‡
W/L <sup>b</sup> (%)	72.9 ± 6.8	‡	83 ± 6.1	‡	89 ± 6.2	‡
AMA (cm <sup>2</sup> )	8.0 ± 1.2	‡	9.2 ± 1.3	Δ	9.4 ± 1.4	‡
AFA (cm <sup>2</sup> )	2.2 ± 1.1	‡	3.2 ± 1.5	†	4.5 ± 1.8	‡

AMA, arm muscle area; AFA, arm fat area; BMI, Body mass index; W/L, weight/length index. <sup>a</sup>BMI: Frisancho AR et al [15]; <sup>b</sup>W/L: Krick J et al [16].

Δ Non significant; \* p < 0.05; † p < 0.01; ‡ p < 0.001.

**Table III**  
*Fat mass and fat free mass by BIA and anthropometry in three stages during the nutritional recovery period*

Indicator	N	Initial Mean ± SD	Initial vs 15 d p value	15 days Mean ± SD	15 d vs 30 d p value	30 days Mean ± SD	Initial vs 30 d p value
Body Fat (%) (TSF + SSSF)	13	7.0 ± 2.3	‡	9.9 ± 3.2	‡	13.2 ± 3.8	‡
Body Fat (%) (TSF + CSF)	13	10.3 ± 4.0	‡	12.1 ± 4.7	‡	14.6 ± 5.5	‡
Body Fat by BIA (%)	9	16.3 ± 9.2	*	22.6 ± 9.1	Δ	24.6 ± 12	*
FM anthropometry (kg)	13	0.9 ± 0.4	‡	1.4 ± 0.6	‡	2.0 ± 0.7	‡
FM by BIA (kg)	9	2.1 ± 1.3	*	3.2 ± 1.4	Δ	3.7 ± 1.8	†
FFM anthropometry (kg)	13	11.0 ± 2.0	‡	12.2 ± 2.2	†	12.6 ± 2.1	‡
FFM by BIA (kg)	10	10.5 ± 1.8	Δ	11.2 ± 2	Δ	11.5 ± 2.5	*

TSF: tricipital skin fold; SSSF: sub-scapular skin fold; CSF: calf skin fold; BIA: Bioelectric impedance analysis; FM: Fat mass; FFM: Fat free mass. FM anthropometry vs. BIA: Initial p = 0.008; 15 days p = 0.007; 30 days p = 0.02. FFM anthropometry vs. BIA: Initial, 15 days and 30 days Non significant.

Δ Non significant; \* p < 0.05; † p < 0.01; ‡ p < 0.001.

and kg of fat obtained by anthropometry were lower than those showed by BIA, which showed a greater variance.

## Discussion

Enteral feeding by continuous pump infusion during a four-week period of intensive nutritional support produced significant changes in anthropometric and body composition indicators in children with CP and moderate/severe malnutrition. The majority of studies evaluating the effect of enteral feeding on body composition and anthropometric indicators<sup>1,5,6</sup> have shown significant changes over long periods of time.

It has been recognized that the main goal of body composition measurements in clinical practice is the evaluation of nutritional status by measuring FFM and FM<sup>14</sup>; however, it is important to realize that children with spastic quadriplegia CP had lower fat-free content. Moreover, the lower body weight among children with CP can be caused by leg muscle wasting that is attributable to disuse atrophy<sup>15</sup>. Stevenson et al.<sup>16</sup> have demonstrated that children with moderate and severe CP are smaller, thinner, and lighter than their age- and sex-matched peers without CP, and the difference becomes more pronounced as the children get older. Even with aggressive nutritional rehabilitation in older children with CP, their growth parameters, including body fat, are below the normal range<sup>5</sup>.

It has been mentioned that field methods such as skinfold thickness measurements and BIA are considered valid when applied to healthy children<sup>17</sup>, but they may be less accurate in children with neurologic impairments<sup>20</sup> because these children have altered growth patterns and fat distribution<sup>6</sup>. Rieken et al.<sup>3</sup> have analyzed the validity of skin fold measurements and BIA in children with severe cerebral palsy and have noted that although most studies reported favorable agreement for skin fold measurements and BIA, these conclusions are hampered by small, heterogenic populations, the use of statistical methods that are considered weak and other limitations.

Although BIA is a simple, relatively inexpensive, and easily portable method for estimating TBW, FFM, and percent fat in field, clinical, and laboratory settings, and numerous validation studies have been conducted in children and adolescents, there have been far fewer cross-validation studies, and there is no consensus regarding which equations to use in this population<sup>21</sup>. Additionally, there are also differences in body proportions (e.g., trunk and extremity lengths, skeletal widths) that could have a significant effect on the estimation of FFM and percent fat by BIA because total body resistance is largely determined by segmental resistances in the extremities. These features are particularly important in malnutrition because this disease is characterized by changes in cellular membrane integrity and alterations in fluid balance. In our study, the

body fat (%) was lower with the Slaughter equations throughout the study period than with BIA.

A significant decrease in the percentage of total body water (TBW) at the start vs 30 days ( $p < 0.05$ ) was observed. Furthermore, the volume of TBW (Lt) showed a significant increase in the same period of time ( $p < 0.01$ ) that could be related to an increase in body cell mass (BCM). Likewise, the percentage of extracellular body water (EBW) showed a significant decrease at the start vs 30 days ( $p < 0.01$ ). In addition, the percentage of intracellular body water (IBW) showed a significant decrease at the start vs 30 days ( $p < 0.01$ ), with small changes in the IBW volume. These changes may be influenced by the velocity of the fat free mass and fat mass incorporation, and the fluid redistribution.

In conclusion, our results show that intensive nutritional support for a four-week period produces significant changes in body composition; that the increase on the percentage of body fat by Slaughter equations is more consistent and has less variability than with BIA during the four-week-period; and that the percentage of fat incorporation is higher in sub scapular skin folds (trunk) than in tricipital skin folds (extremities). However, we consider that the validity of skin fold measurements and BIA in children with severe protein energy malnutrition and CP during the process of nutritional recovery needs a more robust evaluation.

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## Authors' contributions

Conceived and designed the experiments: AAGC, EVG, IES. Performed the experiments: AAGC, EVG, AIIG. Analyzed data: AAGC, EVG, ERV, 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.

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