Association between gross motor function and nutritional status in children with cerebral palsy: a cross-sectional study from Colombia

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This article is commented on by Leandro on pages 893–894 of this issue.

Cerebral palsy (CP) is a group of non-progressive disorders of movement and posture that result from a lesion occurring in the developing foetal or infant brain.1 In developed countries, the prevalence of CP ranges from 2.0 to 3.5 per 1000 live births, which is a similar estimate to that reported in resource-poor settings.2 There are no population-based studies that allow estimation of the prevalence of CP in Latin America; however, in a clinic-based study, Redon et al.3 reported that the prevalence of CP in Mexico ranged from 3.0 to 4.0 cases per 10 000 live births between 1998 and 2002. To our knowledge, no studies have reported national estimates of CP prevalence in Colombia. We identified two studies, one in the urban area of Sabaneta (State of Antioquia) and the other in two units at the Hospital Universitario San Jose, Popayan (State of Cauca), that reported prevalence estimates of 1.19 per 1000 in children under 10 years and 16.2% in children with a mean age of 4 years respectively.3,5

It is well documented that CP is associated with poor growth, and that the deviation from the normal growth parameter values (e.g. World Health Organization [WHO]-based, or based on Centers for Disease Control and Prevention normal values in the USA) increases with increasing levels of gross motor dysfunction.6–11 Malnutrition and growth restriction are associated both with nutritional and with non-nutritional factors, including impaired oral–motor function, gastroesophageal reflux, aspiration and pneumonia,12 negative neurotropic effects, and endocrine abnormalities.13 Socioeconomic factors have also been associated with nutritional status and prognosis in children with CP;14 however, there is little information about the relationship between CP and malnutrition in developing countries, where poverty might accentuate the vulnerability of these children.15

The aim of our study was to determine the association between gross motor function, as a measurement of CP severity, and nutritional status in children aged 2 to 12 years who live in an urban area of a developing country.

METHOD

We conducted a cross-sectional study in 177 children (ages 2–12y, 59.3% male) with a diagnosis of CP who were attending rehabilitation centres in Bucaramanga, Colombia (2012–2013). A physiotherapist evaluated patients using the Gross Motor Function Classification System (GMFCS, levels I to V). Nutritional status was evaluated by nutritionists and classified according to the World Health Organization growth charts. We used linear and multinomial logistic regression methods to determine the associations.

RESULTS

There were 39.5%, 6.8%, 5.6%, 16.4%, and 31.6% patients classified in levels I to V respectively. The mean adjusted differences for weight-for-age, height-for-age, BMI-for-age, and height-for-weight z-scores were significantly larger for children classified in levels II to V compared with those in level I. The children classified in levels IV and V were more likely to have malnutrition (adjusted odds ratio [OR] 5.64; 95% confidence interval [CI] 2.27–14.0) and stunting (OR 8.42; 95% CI 2.90–24.4) than those classified in GMFCS levels I to III.

INTERPRETATION

Stunting and malnutrition are prevalent conditions among paediatric patients with CP, and both are directly associated with higher levels of gross motor dysfunction.
rehabilitation centres in the Metropolitan Area of Bucaramanga, Colombia, between 1 March 2012 and 31 December 2013. A physiotherapist from the study evaluated the muscle tone of all eligible children to confirm the diagnosis of CP. Children were excluded if they had diagnoses in their medical records that included genetic, metabolic, neurodegenerative, and rare disorders that might affect their growth.

We conducted interviews with parents or legal guardians to assess patients’ socio-demographic characteristics, medical history, current disability level, feeding difficulties, and access to and utilization of rehabilitation services (physical, occupational, and language therapy). All children underwent a physical examination by a physiotherapist to determine gross motor function by applying the Gross Motor Function Classification System (GMFCS).16 Height was measured to the nearest 0.5cm by using a wall-mounted stadiometer (SECA 213). For children who had difficulty standing fully erect, knee height was measured with the use of an anthropometer (Martin Anthropometer GPM). Knee height was used to predict height by using equations that were developed for children with CP.17 Body weight was measured to the nearest 0.1kg using portable electronic scales (Tanita Body Fat Monitor BF689). A nutritionist performed these evaluations.

Nutritional status and growth parameters were evaluated according to the WHO sex-specific weight-for-age, height-for-age, and body mass index-for-age (BMI-for-age) growth charts using the ANTHRO and ANTHRO-PLUS software packages.18 We estimated body composition by measuring subscapular and tricipital skinfolds to the nearest 0.1mm (Slim Guide Skinfold) and the arm circumference to the nearest 1.0mm (LUFKIN metal tape measure/W606PM). We defined abnormal tricipital skinfold and arm circumference values using the published reference tables.19 All anthropometric measures were conducted twice, and their average was used in the analyses. The Ethics Committee of the Instituto del Corazon de Bucaramanga approved this study, and we obtained written consent from each patient’s parents or legal guardians.

Statistical analyses
A skewness/kurtosis test was used to determine the normal distribution of all continuous variables. Age is presented as median and interquartile range (IQR) and all the other continuous variables are presented as means and standard deviations. Counts and proportions were calculated for discrete variables. In categorical variables, differences across levels of gross motor function were tested using $\chi^2$ and Fisher’s exact tests when the number of events was $<5$. For non-normally distributed variables (i.e., age), a Kruskal–Wallis test was used; whereas for normally distributed variables, analysis of variance tests were used.

Means and differences (95% confidence intervals [CI]) of weight-for-age, height-for-age, BMI-for-age, weight-for-height, tricipital skinfold-for-age, and subscapular skinfold-for-age z-scores between the levels of gross motor function were estimated using multivariate linear regression analyses adjusting for age; sex; physical, occupational, and language therapy utilization; gastrointestinal symptoms and signs; and feeding route.

Finally, multinomial logistic regression analyses were used to estimate odds ratios (OR) and 95% CI. The dependent variables were three categories of weight-for-age, height-for-age, and BMI-for-age with normal categories used as base outcomes. Initially, crude models were fitted including levels of gross motor function as the independent variable with two categories: levels I to III as reference group and levels IV and V; then multiple multinomial logistic regression analyses were applied adjusting for the same covariates. A $p$ value of $<0.05$ was considered indicative of statistical significance. All analyses were conducted using Stata/MP version 12.1 (StataCorp, College Station, TX, USA).

RESULTS
We evaluated 177 children with a clinical diagnosis of CP (median 6.5y, interquartile range [IQR] 4.4–9.0y; 59.3% males) (Table I). According to the GMFCS, there were 70 (39.5%), 12 (6.8%), 10 (5.6%), 29 (16.4%), and 56 (31.6%) patients classified in levels I to V respectively. Approximately three of every 10 patients belonged to low-income families (<$283, 283–566, >$566 US dollars monthly); however, almost all (98.9%) were covered by a health insurance plan. Overall, there were no differences in either socioeconomic characteristics or health care access/ use according to the GMFCS levels.

A clinical history of prematurity was reported in 75 (46.0%) children, with no difference across the GMFCS levels ($p=0.754$). The three most common deficiencies reported by caregivers were those related to the nervous system (44.1%), movement (39.5%), and language (12.4%). Constipation (49.7%), chewing difficulties (49.2%), food refusal (44.6%), sialorrhoea (42.4%), and sucking difficulties (38.4%) were the most frequently reported gastrointestinal problems by caregivers. Furthermore, constipation and chewing difficulties were associated with advanced levels of motor dysfunction.

The level of motor function was associated with nutritional status, as determined by anthropometry. The mean adjusted deviations from level I of the GMFCS for weight-for-age, height-for-age, BMI-for-age, and height-for-weight z-scores were progressively larger for children classified in GMFCS levels II, III, IV, and V compared...
with those classified in level I. In other words, we observed lower z-scores among children with more pronounced motor dysfunction (Fig. 1). Although we found a linear trend between tricipital and subscapular skinfold z-scores and the GMFCS, only the differences between patients classified in level V and those classified in level I were significant: −1.6 (95% CI −2.7 to −0.6) for tricipital skinfold; −2.1 (95% CI −3.5 to −0.6) for subscapular skinfold. However, we did not find a relationship between arm circumference z-score and motor function.

According to the WHO classification, we found 89 (63.1%) patients who had mild or moderate/severe malnutrition using weight-for-age, 117 (66.4%) who had mild or moderate/severe stunting, and 81 (46.3%) who had mild or moderate/severe malnutrition using BMI-for-age. The overall prevalence of overweight and obesity was 16%, and they were higher among patients with better motor function than among those with poorer motor function. On the basis of weight-for-age, we observed a significantly higher prevalence of malnutrition among patients with lower motor function (p < 0.001). Although we also observed this association for BMI-for-age, the relationship between this index and the prevalence of malnutrition was not gradual: The prevalence of mild or moderate/severe stunting increased significantly (from 41.4% in patients in GMFCS level I to 91.0% in patients in GMFCS level V) as the gross motor function declined (p < 0.001) (Table II).

The adjusted OR for mild or moderate/severe malnutrition, compared with a normal BMI-for-age, was 5.64 (95% CI 2.27–14.0) among patients in GMFCS levels IV and V versus levels I to III. There was no evidence of a significant association between GMFCS and overweight or obesity using BMI-for-age (adjusted OR 0.71; 95% CI 0.18–2.73). Finally, the adjusted OR for mild or moderate/severe stunting, compared with a normal height-for-age, was 8.42 (95% CI 2.90–24.4) among patients in GMFCS levels IV and V compared with those in levels I to III (Table III).

**DISCUSSION**

In our study, which was conducted in the largest sample reported of children with CP in Colombia, we observed an association between gross motor function, as evaluated by the GMFCS, and nutritional status. Overall, approximately two out of every three children with CP had either malnutrition or stunting; however, there were no differences in either socioeconomic characteristics or health care access/utilization by motor function levels. We found independent, direct, and significant relationships between the levels of gross motor functioning and the prevalence of malnutrition and stunting.

We determined gross motor function in all of our patients and classified them according to the GMFCS. In contrast to the global neurological evaluation, the GMFCS has the advantage of being clinically significant and emphasizing function rather than disability, which makes it useful for guiding physiotherapy interventions\(^{16}\) and a potential outcome in clinical trials. In our study, approximately half of the children with CP were classified in functional levels IV and V; however, this estimate is not directly comparable with those from previous reports from Colombia because the other studies did not use the GMFCS to evaluate motor function. Compared with international studies, we found that the proportion of children in levels IV and V in our study was higher.\(^{8,10,20,21}\) This difference might be partly explained by the broader and earlier access of

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**Table I: Demographic and socioeconomic characteristics by gross motor function**

| Characteristic                              | I (n=70) | II (n=12) | III (n=10) | IV (n=29) | V (n=56) | All (n=177) | p       |
|---------------------------------------------|----------|-----------|------------|-----------|----------|-------------|---------|
| Age, y (interquartile range)                | 6.7 (4.6–9.5) | 6.0 (4.7–9.4) | 4.6 (3.6–7.4) | 6.0 (3.4) | 5.3 (2.8–8.8) | 6.6 (4.6–9.2) | 0.314   |
| Male (%)                                    | 41 (58.6) | 8 (66.7)  | 6 (60.0)   | 15 (51.7) | 35 (62.5) | 105 (59.3)   | 0.881   |
| Health insurance (%)                        |          |           |            |           |          |             |         |
| Contributory                                | 44 (62.9) | 8 (66.7)  | 7 (70.0)   | 17 (58.6) | 28 (50.0) | 104 (58.8)   | 0.389   |
| Subsidized                                  | 24 (34.2) | 3 (25.0)  | 3 (30.0)   | 12 (41.4) | 27 (48.2) | 69 (39.0)    | 0.998   |
| Other\(^a\)                                  | 2 (2.9)   | 0 (0.0)   | 0 (0.0)    | 0 (0.0)   | 0 (0.0)   | 2 (1.1)      |         |
| Uninsured                                   | 0 (0.0)   | 1 (8.3)   | 0 (0.0)    | 0 (0.0)   | 1 (1.8)   | 2 (1.1)      |         |
| Therapy (utilization) (%)                   |          |           |            |           |          |             |         |
| Physical                                    | 47 (68.1) | 10 (83.3) | 9 (90.0)   | 23 (79.3) | 47 (85.5) | 136 (77.7)   | 0.179   |
| Occupational                                | 46 (70.8) | 9 (75.0)  | 7 (70.0)   | 17 (65.4) | 36 (70.6) | 115 (70.1)   | 0.983   |
| Language                                    | 49 (71.0) | 8 (72.7)  | 8 (80.0)   | 24 (82.8) | 45 (83.3) | 134 (77.5)   | 0.515   |
| Socioeconomic status (%)                    |          |           |            |           |          |             |         |
| Level 1 (lowest)                            | 20 (28.5) | 1 (8.3)   | 1 (10.0)   | 6 (20.7)  | 21 (37.5) | 49 (27.7)    | 0.411   |
| Level 2                                     | 25 (35.7) | 8 (66.7)  | 6 (60.0)   | 10 (34.5) | 17 (30.4) | 66 (37.3)    |         |
| Level 3                                     | 16 (22.9) | 3 (25.0)  | 2 (20.0)   | 10 (34.5) | 13 (23.2) | 44 (24.9)    |         |
| Level 4 (highest)                           | 9 (12.9)  | 0 (0.0)   | 1 (10.0)   | 3 (10.3)  | 5 (8.9)   | 18 (10.1)    |         |
| Household income (USD)\(^b\)                |          |           |            |           |          |             |         |
| ≤283                                       | 18 (26.1) | 5 (41.7)  | 2 (20.0)   | 7 (25.0)  | 20 (36.4) | 52 (29.9)    | 0.528   |
| >283–566                                   | 36 (52.2) | 6 (50.0)  | 7 (70.0)   | 18 (64.3) | 30 (54.6) | 97 (55.8)    |         |
| >566                                       | 10 (14.5) | 0 (0.0)   | 0 (0.0)    | 3 (10.7)  | 3 (5.5)   | 16 (9.2)     |         |
| Not reported                                | 5 (7.2)   | 1 (8.3)   | 1 (10.0)   | 0 (0.0)   | 2 (3.5)   | 9 (5.1)      |         |

\(^a\) Other health insurance: provided through government funds. \(^b\) Minimum monthly wage is approximately USD283.
patients with CP to more intensive and technologically advanced rehabilitation therapies in developed countries than in developing economies.

We did not observe differences in gross motor function across socioeconomic position or health care access/utilization. This result is consistent with the absence of a socioeconomic gradient with gross motor functional ability among patients with CP from African-American and Hispanic ethnic groups in the USA, as reported by Wu et al., specifically among predominantly disadvantaged populations. Because our patients belonged primarily to the lowest spectrum of socioeconomic status (approximately two-thirds were from socioeconomic statuses I and II), the existence of a gradient cannot be excluded from our results owing to the high socioeconomic homogeneity.

To our knowledge, this investigation is the first to evaluate the association between gross motor function and nutritional status in paediatric outpatients from Latin America. We observed that the z-scores of anthropometric parameters, such as weight-for-age, BMI-for-age, tricipital and subscapular skinfolds, and height-for-age, progressively decreased as the levels of GMFCS increased. Our findings are consistent with results from studies conducted in children from developed countries. The observed associations are due in part to the coexistence in patients with CP of gross motor and gastrointestinal dysfunctions such as constipation, chewing difficulties, food refusal, salivorrhoea,
A relevant finding of this study is the existence of a double burden of malnutrition and overweight in pediatric outpatients with CP. We observed high proportions of overweight (16.0%) and malnutrition (46.3%) in our patients; the overweight findings are comparable to those of other studies from industrialized countries. However, malnutrition in patients with CP might also be explained by nutritional and non-nutritional factors such as difficulty in the feeding process, gastrointestinal disorders, gastroesophageal reflux, increased muscle tone, muscle spasms and involuntary movements, and limited availability of nutritive foods.

A limitation of this study was the convenience sample, although we tried to consider all children who were attending rehabilitation centres in the Metropolitan Area of Bucaramanga. Data missing because of non-responses were not quantified in the study, and the data sample may not be representative of all children with CP in Bucaramanga and its Metropolitan Area. Furthermore, nutritional status was assessed using anthropometric measurements instead of more accurate methods, such as dual-energy X-ray absorptiometry, and we used growth standards by the WHO, which do not have reference parameters for Colombian children with CP.

Although this study may not be entirely generalizable, the broad agreement with many other studies from industrialized countries suggests that many of these results, taken together with the previous results obtained in non-developing (i.e. already developed) countries, may apply well to Latin America.

**ACKNOWLEDGEMENTS**

We thank all the rehabilitation centres, children, and families who participated in the study. We also thank the nutrition and physiotherapy students and our research assistant for their help with recruitment and data collection. This study was funded by grants from the Departamento Administrativo de Ciencia, Tecnología e Innovación (COLCIENCIAS) with code 11025433170, Universidad Industrial de Santander, and Universidad de Santander with code 020-11. The authors have stated that they had no interests that could be perceived as posing a conflict or bias.

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**Table II: Nutritional status according to World Health Organization categories and gross motor function**

| Anthropometric index | I (n=70) | II (n=12) | III (n=10) | IV (n=29) | V (n=55) | All (n=176) | p |
|----------------------|----------|-----------|-----------|-----------|----------|-------------|---|
| Weight-for-age<sup>a</sup> (%) |          |           |           |           |          |             |   |
| Mild and moderate/severe malnutrition | 22 (40.7) | 5 (45.5) | 5 (55.6) | 16 (72.7) | 41 (91.1) | 89 (63.1) | <0.001 |
| Normal | 24 (44.4) | 5 (45.5) | 3 (33.3) | 6 (27.3) | 4 (8.9) | 42 (29.8) |          |
| Overweight/obesity | 8 (14.9) | 1 (9.0) | 1 (11.1) | 0 (0.0) | 0 (0.0) | 10 (7.1) |          |
| Height-for-age (%) |          |           |           |           |          |             |   |
| Mild and moderate/severe stunting | 29 (41.4) | 8 (66.7) | 7 (70.0) | 23 (79.3) | 50 (91.0) | 117 (66.4) | <0.001 |
| Normal | 41 (58.6) | 4 (33.3) | 3 (30.0) | 6 (20.7) | 5 (9.0) | 59 (33.6) |          |
| BMI-for-age (%) |          |           |           |           |          |             |   |
| Mild and moderate/severe malnutrition | 23 (33.3) | 1 (8.3) | 2 (20.0) | 13 (44.8) | 42 (76.4) | 81 (46.3) | <0.001 |
| Normal | 30 (43.5) | 9 (75.0) | 4 (40.0) | 12 (41.4) | 11 (20.0) | 66 (37.7) |          |
| Overweight/obesity | 16 (23.2) | 2 (16.7) | 4 (40.0) | 4 (13.8) | 2 (3.6) | 28 (16.0) |          |
| AC–10th centile<sup>b</sup> | 16 (22.9) | 3 (25.0) | 2 (20.0) | 13 (44.8) | 34 (60.7) | 68 (38.4) | <0.001 |
| TSF–10th centile<sup>b</sup> | 19 (27.1) | 2 (16.7) | 5 (50.0) | 16 (55.2) | 40 (71.4) | 82 (46.3) | <0.001 |

<sup>a</sup>Estimated among patients ≤10y: 54 (I), 11 (II), 9 (III), 22 (IV), 45 (V).  
<sup>b</sup>Patients with index value <10th centile according to Frisancho et al. (1990). Mild and moderate/severe malnutrition according to WHO criteria. BMI, body mass index; AC, arm circumference; TSF, tricipital skinfold.

**Table III: Association between Gross Motor Function Classification System level (IV-V vs I-III) and nutritional status**

| Anthropometric index | Model | Crude OR (95% CI) | Adjusted<sup>a</sup> OR (95% CI) |
|----------------------|-------|-------------------|----------------------------------|
| Weight-for-age<sup>a</sup> |       |                   |                                  |
| Mild and moderate/severe malnutrition | 5.70 (2.48–13.1) | 6.56 (2.04–21.1) |                |
| Normal | 1.00 | 1.00 |                                  |
| Overweight/obesity | Not calculable | Not calculable |                                  |
| Height-for-age<sup>a</sup> |       |                   |                                  |
| Moderate/severe stunting | 8.30 (3.78–18.2) | 8.60 (2.93–25.2) |                |
| Mild stunting | 4.70 (1.73–12.8) | 7.53 (1.86–30.6) |                |
| Normal | 1.00 | 1.00 |                                  |
| BMI-for-age<sup>a</sup> |       |                   |                                  |
| Mild and moderate/severe malnutrition | 3.96 (1.99–7.87) | 5.64 (2.27–14.0) |                |
| Normal | 1.00 | 1.00 |                                  |
| Overweight/obesity | 0.51 (0.18–1.44) | 0.71 (0.18–2.73) |                |

<sup>a</sup>Adjusted for age, sex, physical, occupational, and language therapy utilization, gastrointestinal symptoms and signs (incoordination, sucking, chewing, and swallowing difficulties), and feeding route. Reference group: Gross Motor Function Classification System levels I–III. Mild and moderate/severe malnutrition according to WHO criteria.
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