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Growth and neuropsychological developmental correlates in children with autism and cerebral palsy - a pilot study

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Summary. Background. Cerebral palsy (CP) and autism spectrum disorder (ASD) are neurodevelopmental conditions that affect physical growth and developmental outcomes. While distinct, both can influence neuropsychological development, yet limited research has examined how growth indicators relate to developmental profiles in these groups. This pilot cross-sectional study examines the relationship between physical growth and neuropsychological development in children with CP and ASD, and compares their developmental characteristics. **Methods.** This cross-sectional study included 27 children (CP: n=14; ASD: n=13). Anthropometric assessments included height-for-age (HAZ), weight-for-age (WAZ), BMI-for-age (BMIAZ), mid-upper arm circumference-for-age (MUACAZ), and skinfold thickness Z-scores (TSFAZ, SSFAZ). Neuropsychological development was measured using the Developmental Profile 3 (DP-3), covering physical, adaptive, cognitive, social-emotional, and communication domains. **Results.** Children with ASD had significantly higher scores in physical development (median: 83.5 vs. 54.0, p=0.006), adaptive behavior (81.0 vs. 53.0, p=0.003), and overall development (78.0 vs. 58.0, p=0.035) than those with CP. No differences were found in cognitive, social-emotional, or communication domains. In the full sample, WAZ significantly correlated with adaptive behavior (r=0.491, p=0.015) and overall development (r=0.439, p=0.032). MUACAZ and TSFAZ were also associated with specific developmental domains (e.g., MUACAZ and adaptive behavior: r=0.445, p=0.033). Linear regression analysis confirmed that WAZ significantly predicted neurodevelopmental scores (β=6.20, p=0.022), explaining 46.5% of the variance when adjusted for age, gender, and parental age (Adjusted R^2=0.465; p=0.040). **Conclusions.** Children with CP show greater growth and developmental delays than those with ASD. Weight-for-age is a key predictor of neurodevelopment, especially adaptive behavior. These findings support integrating nutritional and developmental care in neurodevelopmental interventions.

Key words. Autism spectrum disorder, cerebral palsy, DP-3 developmental screening, growth indicators, neuropsychological development, weight-for-age.

Correlazioni tra crescita e sviluppo neuropsicologico nei bambini con autismo e paralisi cerebrale: uno studio pilota.

Riassunto. Introduzione. La paralisi cerebrale (PCI) e il disturbo dello spettro autistico (DSA) sono condizioni neuroevolutive che influenzano la crescita fisica e gli esiti dello sviluppo. Sebbene distinte, entrambe possono influenzare lo sviluppo neuropsicologico; tuttavia, ricerche limitate hanno esaminato la relazione tra gli indicatori di crescita e i profili di sviluppo in questi gruppi. Questo studio trasversale pilota esamina la relazione tra crescita fisica e sviluppo neuropsicologico nei bambini con PCI e DSA e ne confronta le caratteristiche evolutive. **Metodi.** Questo studio trasversale ha incluso 27 bambini (PCI: n=14; DSA: n=13). Le valutazioni antropometriche includevano altezza per età (HAZ), peso per età (WAZ), BMI per età (BMIAZ), circonferenza della parte centrale superiore del braccio per età (MUACAZ) e punteggi Z dello spessore delle pliche cutanee (TSFAZ, SSFAZ). Lo sviluppo neuropsicologico è stato misurato utilizzando il Developmental Profile 3 (DP-3), che copre i domini fisico, adattivo, cognitivo, socio-emotivo e comunicativo. **Risultati.** I bambini con ASD hanno ottenuto punteggi significativamente più alti nello sviluppo fisico (mediana: 83,5 vs 54,0, p=0,006), nel comportamento adattivo (81,0 vs 53,0, p=0,003) e nello sviluppo complessivo (78,0 vs 58,0, p=0,035) rispetto a quelli con paralisi cerebrale infantile. Non sono state riscontrate differenze nei domini cognitivo, socio-emotivo o comunicativo. Nell'intero campione, la WAZ è risultata significativamente correlata al comportamento adattivo (r=0,491, p=0,015) e allo sviluppo complessivo (r=0,439, p=0,032). MUACAZ e TSFAZ sono stati inoltre associati a specifici domini di sviluppo (ad esempio, MUACAZ e comportamento adattivo: r=0,445, p=0,033). L'analisi di regressione lineare ha confermato che WAZ prediceva significativamente i punteggi di neurosviluppo (β=6,20, p=0,022), spiegando il 46,5% della varianza quando aggiustata per età, sesso ed età dei genitori (R^2 aggiustato=0,465; p=0,040). **Conclusioni:** i bambini con paralisi cerebrale infantile mostrano maggiori ritardi di crescita e sviluppo rispetto a quelli con disturbi dello spettro autistico. Il rapporto peso/età è un fattore predittivo chiave del neurosviluppo, in particolare del comportamento adattivo. Questi risultati supportano l'integrazione dell'assistenza nutrizionale e dello sviluppo negli interventi di neurosviluppo.

Parole chiave. Disturbo dello spettro autistico, indicatori di crescita, paralisi cerebrale, peso per età, screening dello sviluppo DP-3, sviluppo neuropsicologico.

Introduction

Autism spectrum disorder (ASD) and cerebral palsy (CP) are two distinct yet sometimes co-occurring neurodevelopmental conditions that present significant challenges in diagnosis, management, and intervention. CP is primarily characterized by motor impairments resulting from brain injury occurring before, during, or shortly after birth, with a prevalence of approximately 3.1-3.6 per 1,000 children in the United States – a rate that has remained relatively stable over time[1,2]. In contrast, ASD is defined by persistent deficits in social communication alongside restricted and repetitive behaviors and has shown a marked increase in prevalence, rising by an estimated 9.3% annually between 1996 and 2010[3]. The co-occurrence of ASD in children with CP has been reported in 6.9-8.7% of cases[2,3], further complicating developmental trajectories and clinical care.

Growth and neuropsychological development are closely interconnected pillars of child health, particularly in the context of developmental disorders. Early identification and targeted intervention can profoundly influence long-term outcomes across cognitive, behavioral, and functional domains[4,5]. Children with ASD or CP often present with delays in motor skills, cognitive functioning, and adaptive behavior, necessitating continuous monitoring and individualized support[6]. Motor skills, a key component of neuropsychological assessment, frequently serve as early indicators of broader developmental concerns[7]. For example, children with ASD or attention-deficit/hyperactivity disorder (ADHD) may exhibit distinct neurodevelopmental profiles requiring tailored therapeutic approaches[6].

Understanding the interplay between physical growth and neuropsychological development is critical in neurodiverse populations. Anthropometric indicators such as height and weight can provide valuable insights into biological and environmental influences on development. Deviations from typical growth trajectories in early childhood often coincide with neurodevelopmental impairments, suggesting shared underlying mechanisms and underscoring the need for integrated models of care[8,9].

Research has increasingly highlighted the predictive value of early growth for later developmental outcomes. A large cohort study of 12,368 term-born Belarusian children demonstrated that increased length/height from birth to 6.5 years was significantly associated with better subsequent cognitive performance, emphasizing early growth as a developmental marker[10]. Likewise, a systematic review of 30 studies confirmed the long-term cognitive and behavioral consequences of severe childhood malnutrition, reinforcing the importance of timely nutritional interventions[11-13]. Other studies have linked slower physical growth in early childhood with higher risks of neurodevelopmental delay, supporting the inclusion of growth monitoring in routine developmental assessments[14].

The bidirectional relationship between growth and neurodevelopment has also been well documented. Wei et al.[15] showed that suboptimal growth can exacerbate developmental delays, which in turn may further impair somatic growth – creating a feedback loop that can be interrupted only through comprehensive, multidisciplinary interventions. Similarly, Bombin et al.[16] found that abnormal growth patterns were common in children with early-onset psychosis, further illustrating the link between somatic and neuropsychological development.

In this context, the present pilot study examines the associations between anthropometric indicators and neuropsychological development in children with CP and ASD. By exploring how growth metrics correlate with functional developmental domains, the study aims to inform early detection strategies and guide holistic, developmentally sensitive interventions for this vulnerable population. Given the inherent differences between ASD and CP, our aim was not to directly compare the groups for equivalency, but to investigate whether physical growth indicators are associated with developmental parameters in each population – both separately and combined – thereby informing tailored, diagnosis-specific care strategies[17,18].

Materials and methods

Participants

The study included 27 children diagnosed with either autism spectrum disorder (ASD; n=13) or cerebral palsy (CP; n=14). Parents were contacted via phone or email and invited to participate. Eligibility was assessed through initial phone screenings followed by intake interviews with guardians. Written informed consent was obtained from all parents or legal guardians, and all personal data were anonymized for processing and storage in accordance with ethical standards.

A concurrent healthy control group was intentionally omitted to reduce the ethical burden on healthy children and families and to focus on within-disorder variability. Comparisons were made against well-established normative developmental curves and World Health Organization (WHO) growth standards. This approach, considered appropriate for a pilot study, aimed to explore within-group associations between somatic growth and domain-specific neuropsychological outcomes, thereby laying the groundwork for future interventional trials.

ASD diagnoses were established according to DSM-5 criteria, confirmed by a pediatric psychiatrist, and supported by the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) or Autism Diagnostic Interview-Revised (ADI-R) when available. CP diagnoses were based on clinical signs of non-progressive motor impairment, confirmed by a pediatric neurologist, and supplemented with brain imaging and Gross Motor Function Classification System (GMFCS) levels when applicable.

Demographic and social data

Data collected for each participant included sex, age, diagnosis, and gestational age at birth. Parental demographic information – such as age and education level – was also recorded to provide a broader context for interpreting developmental and growth outcomes.

Measures

To investigate the relationship between growth and neuropsychological development, both anthropometric indicators and standardized neuropsychological assessments were collected.

Growth indicators

- *Weight-for-Age Z-score (WAZ)*: measured using a calibrated digital scale; Z-scores calculated according to WHO growth standards.
- *Height-for-Age Z-score (HAZ)*: measured with a stadiometer; Z-scores derived from WHO standards.
- *Body Mass Index-for-Age Z-score (BMIAZ)*: calculated from weight and height; Z-scores based on WHO reference data.
- *Mid-Upper Arm Circumference (MUAC)*: measured with a non-stretchable tape; converted to Z-scores using reference values.
- *Triceps Skinfold Thickness-for-Age Z-score (TSFAZ)*: measured at the midpoint between the acromion and olecranon on the posterior upper arm using a calibrated skinfold caliper; converted to age- and sex-adjusted Z-scores using WHO standards.
- *Subscapular Skinfold Thickness-for-Age Z-score (SSFAZ)*: measured at a 45° angle just below the inferior angle of the scapula using a skinfold caliper; converted to age- and sex-adjusted Z-scores to assess central adiposity.

Neuropsychological development

Neuropsychological development was assessed using the Developmental Profile 3 (DP-3), a standardized instrument evaluating five developmental domains. Four domains were analyzed in this study:

- *Cognitive development*: intellectual abilities and problem-solving skills;
- *Communication*: expressive and receptive language skills;
- *Social-emotional*: social interaction, emotional regulation, and interpersonal skills;
- *Adaptive behavior*: practical skills required for independent and social functioning.

All assessments were administered by trained examiners in a quiet, child-friendly setting to minimize distractions. Scores were standardized, with higher values indicating more advanced development.

Procedure

The study followed a standardized protocol to ensure the accuracy and reliability of data collection and analysis.

Recruitment and consent

Participants were recruited through their parents, who were contacted via phone or email and invited to take part in the study. Eligibility was assessed through initial phone screenings followed by intake interviews. Written informed consent was obtained from parents or legal guardians, and all personal information was anonymized for processing and storage in accordance with ethical requirements.

Data collection

Anthropometric measurements were performed by trained healthcare professionals using standardized equipment and procedures to ensure accuracy. Neuropsychological assessments (DP-3) were conducted individually in a quiet, child-friendly environment to minimize distractions and optimize the reliability of results.

Statistical analysis

As this was an exploratory pilot study, no a priori power analysis was performed. The sample size (n=27) was determined based on feasibility, available resources, and recruitment capacity within a specialized clinical setting. The primary objective was to identify preliminary associations that could inform the design of future, larger-scale, hypothesis-driven studies.

Group differences in neuropsychological development between children with CP and ASD were examined using Independent Samples t-tests for normally distributed variables. Given that some data did not meet normality assumptions, Mann-Whitney U tests

were also applied as non-parametric alternatives.

Associations between growth indicators – WAZ, HAZ, BMIAZ, and MUAC – and neuropsychological development scores were explored using Pearson correlation analysis. Correlation was adjusted for age and gender to address confounding due to group differences. Significant correlations were further interpreted in the context of the study's aims.

To assess the predictive effect of WAZ on neurodevelopmental outcomes, multiple linear regression analyses were conducted, adjusting for age (log-transformed), gender, and parental ages. Model fit was evaluated using R^2, adjusted R^2, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), *F*-statistics, and corresponding *p*-values. Regression coefficients and their significance levels were reported to provide a comprehensive understanding of factors influencing neurodevelopment.

The study was approved by the Ethics Committee of the Medical University of Varna (Protocol No. 134/20.07.2023).

Results

Participant characteristics

The study included a total of 27 children diagnosed with either CP or ASD. The demographic and clinical characteristics of the study sample are summarized in table 1.

This table provides a summary of the key demographic and clinical characteristics of the children and their parents, highlighting significant differences between the CP and ASD groups. The sample was predominantly male, especially in the ASD group. Mothers of children with ASD were older on average compared to mothers of children with CP. The educational levels of parents varied, with a higher proportion of parents of children with ASD holding advanced degrees.

Growth patterns

The analysis of growth measurements between children with CP and ASD revealed significant differences in several key indicators. Notably, children with CP were significantly more likely to have WAZ below -2, indicating a higher prevalence of underweight conditions compared to children with ASD (p=0.005). There were also trends suggesting that children with CP had lower HAZ and BMIAZ compared to those with ASD, although these differences were not statistically significant (p=0.059 for both).

Other growth indicators, such as MUAC, TSFAZ, and SSFAZ, showed no significant differences between the two groups. Detailed information on these growth indicators is provided in table 2. Overall, the results suggest that children with CP exhibit more pronounced growth impairments, particularly in weight-related measures, compared to their peers with ASD (table 2).

Neuropsychological development

The neuropsychological development of the children was assessed using the DP-3, which evaluates key developmental domains including physical development, adaptive behavior, social-emotional skills,

Table 2. Comparison of growth indicators between children with cerebral palsy and autism spectrum disorder.

Growth Indicator	Cerebral Palsy (n=12)	Autism (n=12)	p-value
WAZ < -2, n (%)	6/12 (50.0%)	0 (0%)	**0.005**
HAZ < -2, n (%)	5/12 (41.7%)	1/12 (8.3%)	0.059
BMIAZ < -2, n (%)	5/12 (41.7%)	1/12 (8.3%)	0.059
MUAC < -2, n (%)	1/12 (8.3%)	0 (0%)	0.328
TSFAZ < -2, n (%)	1/12 (8.3%)	0 (0%)	0.350
SSFAZ < -2, n (%)	0 (0%)	1/12 (10.0%)	0.262

Table 1. Demographic and clinical characteristics: statistically significant p-values (p<0.05) are bolded.

Characteristics	Cerebral palsy (n=13)	Autism (n=14)	p-value
Male, n (%)	4/13 (30.8%)	12/14 (85.7%)	**0.004**
Age, mean (SD)	5.8 (2.7)	8.5(1.7)	**0.005**
GMFCS moderate to severe, n (%)	2/13 (15.4%)	0 (0%)	–
Mother age, mean (SD)	35.44 (6.69)	42.42 (7.10)	**0.034**
Father age, mean (SD)	38.25 (3.81)	43.64 (7.34)	0.076
Ethnicity: Bulgarian, n (%)	11/13 (84.6%)	10/14 (71.4%)	0.341
Education mother: up to secondary, n (%)	6 (66.7%)	5 (35.7%)	0.147
Education mother: master, PhD, n (%)	3 (33.3%)	9 (64.3%)	0.147
Education father: up to secondary, n (%)	5 (62.5%)	4 (30.8%)	0.154
Education father: master, PhD, n (%)	3 (37.5%)	9 (69.2%)	0.154

cognitive development, and communication. The findings from these assessments are presented in table 3.

The DP-3 neuropsychological development of children analysis revealed notable differences between the two groups across several of these areas.

Children in the ASD group exhibited significantly higher median scores in physical development compared to those in the CP group (p=0.006), suggesting more advanced motor and sensorimotor skills. A similar pattern emerged in the domain of adaptive behavior, where children with ASD outperformed those with CP (p=0.003), indicating stronger abilities in daily functional tasks, personal care, and environmental adjustment.

In contrast, the two groups did not differ significantly in their social-emotional development scores. Both groups demonstrated similar levels of emotional regulation and social interaction capabilities, as reflected in the comparable median values (p=0.752). Cognitive development scores were likewise similar between the groups, with no statistically significant difference observed (p=0.627), suggesting that intellectual functioning may be comparably affected in both conditions, despite differences in physical and adaptive profiles.

Although the ASD group demonstrated higher median scores in communication, indicating relatively better expressive and receptive language abilities, this difference did not reach statistical significance (p=0.182). However, when considering the total developmental score across all domains, children with ASD once again scored significantly higher than those with CP (p=0.035), emphasizing a broader disparity in overall developmental functioning and highlighting the differential impact these neurodevelopmental disorders have on children's developmental trajectories.

Correlation analysis

The relationship between growth indicators and neuropsychological development was analyzed to identify any significant correlations. The growth indicators included HAZ, WAZ, BMIAZ, and MUAC. The developmental domains assessed were physical development, adaptive behavior, social-emotional skills, cognitive development, communication, and overall development.

To better account for the heterogeneity between conditions, we analyzed correlations separately within each diagnostic group (CP and ASD) (tables 4, 5 and 6).

In children with cerebral palsy, significant positive correlations were observed between MUAC and multiple developmental domains, including adaptive behavior (r=0.625, p=0.030), cognitive development

Table 3. Developmental measures (non-parametric analysis with medians, IQRs, and points). Statistically significant p-values (p<0.05) are bolded.

Developmental measure	Cerebral palsy (n=13)	Autism (n=14)	p-value
Physical development (points)	54.0 (46.0-69.0)	83.5 (78.5-89.0)	**0.006**
Adaptive behavior (points)	53.0 (42.0-69.0)	81.0 (73.0-92.0)	**0.003**
Social-emotional scale (points)	71.0 (42.0-85.0)	69.0 (62.0-77.0)	0.752
Cognitive development (points)	65.0 (41.0-85.0)	70.0 (57.5-85.0)	0.627
Communication (points)	55.0 (42.5-82.0)	73.0 (60.0-80.5)	0.182
Overall development (points)	58.0 (47.0-75.0)	78.0 (70.0-83.5)	0.035

Table 4. correlation between growth indicators and neuropsychological development for cerebral palsy (significant p-values marked with asterisks). Statistically significant p-values (p<0.05) are bolded.

Developmental domains	HAZ (r, p-value)	WAZ (r, p-value)	BMIAZ (r, p-value)	MUAC (r, p-value)	TSFAZ (r, p-value)	SSFAZ (r, p-value)
Physical development	0.432, p=0.161	0.330, p=0.295	0.182, p=0.572	0.442, p=0.150	0.451, p=0.141	0.336, p=0.286
Adaptive behavior	0.581, p=**0.048**	0.474, p=0.120	0.269, p=0.397	0.625, **p=0.030**	0.479, p=0.115	0.415, p=0.180
Social-Emotional Scale	0.261, p=0.413	0.276, p=0.385	0.231, p=0.470	0.431, p=0.162	0.466, p=0.127	0.278, p=0.381
Cognitive development	0.493, p=0.103	0.457, p=0.135	0.311, p=0.326	0.653, p=**0.021**	0.294, p=0.353	0.317, p=0.315
Communication	0.475, p=0.119	0.486, p=0.109	0.351, p=0.263	0.643, **p=0.024**	0.451, p=0.141	0.507, p=0.092
Overall evelopment	0.491, p=0.105	0.441, p=0.151	0.292, p=0.357	0.614, **p=0.034**	0.466, p=0.127	0.406, p=0.190

Table 5. Correlation between growth indicators and neuropsychological development for autism (significant p-values marked with asterisks). Statistically significant p-values (p<0.05) are bolded.

Developmental domains	HAZ (r, p-value)	WAZ (r, p-value)	BMIAZ (r, p-value)	MUAC (r, p-value)	TSFAZ (r, p-value)	SSFAZ (r, p-value)
Physical development	-0.269, p=0.398	-0.246, p=0.441	0.055, p=0.866	-0.078, p=0.819	-0.046, p=0.899	-0.144, p=0.690
Adaptive behavior	0.242, p=0.449	-0.129, p=0.690	-0.139, p=0.668	-0.064, p=0.852	-0.071, p=0.846	-0.179, p=0.620
Social-Emotional Scale	-0.029, p=0.928	-0.046, p=0.888	0.128, p=0.693	-0.233, p=0.490	-0.426, p=0.220	-0.677, **p=0.031**
Cognitive development	-0.215, p=0.502	0.010, p=0.974	0.289, p=0.362	-0.008, p=0.981	-0.125, p=0.732	-0.329, p=0.353
Communication	-0.033, p=0.920	0.086, p=0.791	0.241, p=0.451	0.084, p=0.807	-0.092, p=0.800	-0.381, p=0.278
Overall development	-0.079, p=0.807	-0.058, p=0.859	0.161, p=0.618	-0.065, p=0.850	-0.182, p=0.614	-0.409, p=0.241

Table 6. Correlation between growth indicators and neuropsychological development for autism and cerebral palsy combined together. (Significant p-values marked with asterisks). Statistically significant p-values (p<0.05) are bolded.

Developmental domains	HAZ (r, p-value)	WAZ (r, p-value)	BMIAZ (r, p-value)	MUAC (r, p-value)	TSFAZ (r, p-value)	SSFAZ (r, p-value)
Physical development	0.393, p=0.058	0.394, p=0.057	0.283, p=0.180	0.372, p=0.080	0.474, p=0.026*	0.289, p=0.193
Adaptive behavior	0.572, **p=0.003**	0.491, **p=0.015**	0.298, p=0.158	0.445, **p=0.033**	0.485, **p=0.022**	0.313, p=0.155
Social-Emotional Scale	0.225, p=0.290	0.258, p=0.223	0.244, p=0.250	0.204, p=0.352	0.300, p=0.174	0.025, p=0.912
Cognitive development	0.243, p=0.252	0.333, p=0.112	0.319, p=0.129	0.316, p=0.142	0.196, p=0.383	0.073, p=0.747
Communication	0.375, p=0.071	0.448, **p=0.028**	0.366, p=0.079	0.417, **p=0.047**	0.386, p=0.076	0.259, p=0.245
Overall development	0.417, **p=0.043**	0.439, **p=0.032**	0.341, p=0.103	0.401, p=0.058	0.417, p=0.053	0.221, p=0.324

(r=0.653, p=0.021), communication (r=0.643, p=0.024), and overall development (r=0.614, p=0.034). HAZ was also significantly associated with adaptive behavior (r=0.581, p=0.048).

In the autism group, a significant negative correlation was found between SSFAZ and social-emotional skills (r=-0.677, p=0.031), while no other associations reached statistical significance.

In the combined sample, HAZ and WAZ were significantly correlated with adaptive behavior and overall development. Notably, WAZ also showed significant positive associations with communication (r=0.448, p=0.028), and MUAC correlated with both adaptive behavior (r=0.445, p=0.033) and communication (r=0.417, p=0.047). TSFAZ was associated with physical development (r=0.474, p=0.026) and adaptive behavior (r=0.485, p=0.022).

Linear regression model

Several linear regression models were tested to explore the relationship between growth and demographic indicators and neurodevelopmental outcomes. Among these, the model including WAZ, gender, transformed age, and parental ages demonstrated the best overall fit, with an R^2 of 0.643 and an Adjusted R^2 of 0.465. This suggests that approximately 46.5% of the variance in neurodevelopmental scores can be explained by the combined predictors. The model was statistically significant (F=3.61, p=0.040).

WAZ emerged as a significant positive predictor (β=6.20, p=0.022), indicating that improved weight-for-age is associated with higher neurodevelopmental scores. Gender was also significant, with females scoring 27.23 points lower than males on average (p=0.012). While not statistically significant, transformed age showed a negative trend (p=0.067), and parental ages showed weak associations –maternal age negatively (p=0.074) and paternal age positively (p=0.103).

This model provided the most robust explanatory power among those tested and highlights the key influence of nutritional status and gender on neurodevelopment in children. Full model coefficients are detailed in table 7.

Table 7. Linear regression analysis: impact of WAZ on neurodevelopment. Statistically significant p-values (p<0.05) are bolded.

Model fit measures									
Model	**R**	**R^2**	**Adjusted R^2**	**AIC**	**BIC**	**F**	**df1**	**df2**	**p-value**
1	0.802	0.643	0.465	129	135	3.61	5	10	**0.040**
Model coefficients									
Predictor	**Estimate (β)**		**SE**	**95% CI (lower-upper)**		**t**		**p-value**	
Transformed age	-3.74		1.822	-7.802-0.315		-2.06		0.067	
Gender (female vs. male)	-27.23		8.876	-47.008--7.454		-3.07		0.012	
Mother's age	-1.74		0.872	-3.681-0.206		-1.99		0.074	
Father's age	1.73		0.963	-0.420-3.873		1.79		0.103	
WAZ	6.20		2.300	1.074-11.323		2.70		0.022	

Discussion

This study provides new insights into the complex relationship between physical growth and neuropsychological development in children with CP or ASD. While the clinical characteristics of ASD and CP differ substantially, our design allowed for the identification of distinct patterns of association between growth indicators and developmental domains within each diagnostic group. These exploratory findings contribute to the existing body of literature and form a basis for developing condition-specific hypotheses in future research with larger, stratified cohorts.

Growth patterns

Consistent with previous reports, children with CP in our sample exhibited significant growth deficits compared with their peers with ASD[19,20]. These impairments are likely multifactorial, involving feeding difficulties, oral-motor dysfunction, and increased energy expenditure due to spasticity and motor impairments as observed for other disorders[1,19-21]. In this cohort, the higher prevalence of underweight status and lower BMI *z*-scores among children with CP underscores the need for individualized nutritional strategies aimed at promoting adequate somatic growth. Addressing such deficits early is crucial, given the strong evidence linking early growth trajectories with later cognitive and behavioral outcomes[10,13]. Failure to do so may exacerbate neurodevelopmental challenges in this already high-risk population.

Children with short stature and CP typically demonstrate reduced height, weight, and BMI compared with typically developing peers, with the degree of impairment closely associated with motor dysfunction severity and feeding limitations[24,25]. Those with unilateral (hemiplegic) CP often have growth trajectories similar to typically developing children. In contrast, children with bilateral CP – particularly at higher Gross Motor Function Classification System (GMFCS) levels (III-V) – frequently present with markedly lower height-for-age, weight-for-age, and BMI-for-age *z*-scores. These deficits tend to become more pronounced with increasing age and functional severity[24,26,27].

Feeding difficulties, including oropharyngeal dysphagia, are common in children with more severe CP and are independently associated with further reductions in growth parameters[28,29]. Although gastrostomy tube feeding can improve weight gain, it does not consistently enhance linear growth[24,29]. For this reason, the American Academy of Pediatrics recommends the use of CP-specific growth charts stratified by GMFCS level, as standard WHO or CDC growth curves may not accurately capture expected growth patterns in this population[30].

Parental education was included in this study as a contextual sociodemographic variable to approximate socioeconomic status. While no direct associations with developmental outcomes were observed in this small sample, it provides valuable background information. Parental age – particularly maternal age – was also included in regression models and demonstrated a trend-level relationship with developmental outcomes, warranting further investigation in larger cohorts.

Neuropsychological development

Children with ASD in this study demonstrated significantly better physical development, adaptive behavior, and overall developmental profiles compared with children with CP. This finding aligns with previous research indicating that the profound motor impairments characteristic of CP often limits physical activity and reduce opportunities for adaptive skill acquisition[31]. Conversely, while children with ASD face substantial challenges in communication

and social interaction, they generally do not experience the same degree of motor limitation, which may partly explain their relatively more favorable outcomes in physical and adaptive domains.

Children with CP, by definition, have persistent motor impairments and activity limitations due to non-progressive disturbances in the developing brain, frequently accompanied by comorbidities such as intellectual disability (49%), epilepsy (35%), and behavioral disorders (26%)[32,33]. These comorbidities, together with primary motor deficits, contribute to substantial limitations in physical development and adaptive functioning. Even among children with hemiplegic CP, who often have higher mobility, up to 34% present with impaired adaptive skills. Moreover, adaptive behavior in CP is more strongly influenced by comorbidities – such as ASD and lower communication functioning – than by motor severity alone[34].

In contrast, although children with ASD often show delays in motor development and marked deficits in adaptive behavior – particularly in socialization and communication – these impairments are generally less severe and less globally distributed than those observed in CP. While children with ASD exhibit reduced levels of physical activity and motor performance compared with typically developing peers, their motor challenges are not as profound as in CP[35,36]. Furthermore, adaptive behavior in ASD is closely linked to executive functioning and cognitive abilities, with developmental profiles often less globally impaired, particularly in the absence of co-occurring intellectual disability[37].

Overall, these findings underscore the need for condition-specific developmental monitoring and intervention. For children with CP, management strategies should integrate neurocognitive support with nutritional optimization and motor rehabilitation. In ASD, interventions should prioritize targeted social, communicative, and behavioral therapies, while also addressing motor skills when deficits are present.

Our correlation analysis revealed meaningful associations between growth indicators and developmental outcomes, particularly among children with CP. MUAC, a sensitive proxy for nutritional status, was significantly correlated with adaptive behavior, communication, cognitive development, and overall development in this group – emphasizing the central role of adequate nutrition in supporting neurodevelopmental progress. HAZ also emerged as a relevant marker, particularly for adaptive functioning.

In contrast, among children with ASD, growth indicators showed weaker and largely non-significant associations, with one notable exception: a negative correlation between subscapular skinfold thickness and social-emotional skills. This may reflect the complex interplay between central adiposity and emotional regulation in ASD. In the combined sample, both WAZ and MUAC retained significant correlations with multiple developmental domains, underscoring the broader importance of early growth and body composition in shaping neuropsychological outcomes.

These findings align with the broader literature demonstrating the role of adequate nutrition and growth in supporting physical and functional development[38]. Positive correlations between HAZ and MUAC with adaptive behavior suggest that better growth and nutritional status can enhance daily functional abilities. Similarly, the associations between WAZ and MUAC with communication skills indicate that adequate nutrition may support the development of effective communication—an essential component of social interaction and overall quality of life[39,40].

Consistent with previous studies, growth indicators such as weight, height, and BMI are strongly associated with developmental outcomes in children with CP. Poorer growth has been linked to more severe motor impairments, feeding difficulties, and adverse cognitive and health outcomes[24,25,27,28,41]. Children with mild motor impairment (GMFCS levels I-II) or unilateral CP generally exhibit growth trajectories similar to those of typically developing peers. In contrast, those with bilateral CP or severe motor impairment (GMFCS levels III-V) frequently present with markedly reduced height-for-age, weight-for-age, and BMI-for-age *z*-scores, particularly when oropharyngeal dysphagia or other feeding challenges are present[29,42].

Growth failure is most pronounced in children with severe CP, who also tend to have higher rates of cognitive and motor impairment, greater healthcare utilization, and reduced participation in social activities[29,42]. Feeding difficulties and the need for gastrostomy are associated with both suboptimal growth and more severe developmental limitations. Although gastrostomy feeding can promote weight gain in the most severely affected children, it does not always improve linear growth[24,29]. Additionally, reduced head circumference growth – an indirect marker of brain development – has been observed in children with severe CP or those born small for gestational age and is associated with poorer neurodevelopmental outcomes[29]. For these reasons, the American Academy of Pediatrics recommends longitudinal monitoring using CP-specific growth charts stratified by GMFCS level, as lower weight percentiles are associated with increased mortality risk[30].

The linear regression analysis in our study further highlighted the impact of nutritional status on neurodevelopmental outcomes. WAZ emerged as a significant predictor of multiple developmental domains, including physical development, adaptive behavior, communication, and overall development. In ad-

dition to WAZ, gender was a significant factor, with females exhibiting lower developmental scores. This may reflect both the sex imbalance between groups and gender-specific developmental vulnerabilities, warranting further study. Possible explanations are male predominance in ASD and sex-linked developmental patterns. The substantial proportion of explained variance, as indicated by adjusted R^2 values, underscores the critical role of nutrition in shaping neuropsychological outcomes. These results are consistent with prior research demonstrating the importance of adequate nutrition for optimal growth and developmental trajectories[4,38,43].

The strong predictive capacity of WAZ across several domains highlights the need for targeted nutritional interventions in children with CP and ASD. Ensuring adequate nutrition and regularly monitoring growth indicators could significantly improve developmental trajectories and, ultimately, quality of life in these populations.

Nevertheless, these findings should be interpreted with caution. Given the small sample size, the correlations reported here are exploratory in nature. As with all correlation analyses, causality cannot be inferred, and the observed associations may be influenced by unmeasured confounding variables. Larger, hypothesis-driven studies are needed to confirm these relationships and guide clinical practice.

Strengths and limitations

A key strength of this study is its integrative design, combining detailed anthropometric assessments with standardized neuropsychological evaluations (DP-3). By examining both physical growth indicators and validated developmental domains, the study provides a multidimensional view of the relationship between somatic growth and neurodevelopment in children with CP and ASD, thereby enhancing clinical relevance.

However, several limitations should be acknowledged. First, the relatively small sample size (n=27) limits statistical power and reduces the generalizability of the findings. Second, the absence of a concurrently recruited healthy control group restricts direct comparison to typically developing peers. Although standardized normative data (e.g., WHO z-scores, DP-3 reference curves) were used as benchmarks, such comparisons may not fully capture cultural or contextual influences. Third, while adjustments were made for several demographic variables, residual confounding from unmeasured factors – such as dietary patterns, socioeconomic status, or access to rehabilitation – remains possible. Finally, the cross-sectional design precludes causal inference[44]. The decision to omit a control group was deliberate, aiming to minimize participant burden while enabling ethically sound exploration of within-group associations. Given the small sample size, findings should be considered preliminary and hypothesis-generating rather than confirmatory. In addition to a small sample size, the cross-sectional design precludes causal inference. Developmental outcomes were parent-reported, which may introduce recall or reporting bias. Furthermore, the CP group was heterogeneous regarding severity and functional classification, which could contribute to variability in outcomes.

Future directions

Future research should prioritize longitudinal designs to track growth and neuropsychological development over time, thereby clarifying causal pathways and long-term impacts. Multi-center studies involving larger and more diverse cohorts – spanning varying severity levels of CP and ASD as well as typically developing controls – are needed to enhance external validity. Comparative analyses across geographic and socioeconomic settings would further contextualize findings.

Intervention trials should explore the efficacy of targeted nutritional and therapeutic programs in improving growth and developmental outcomes. Integrating biomarkers, detailed dietary assessments, and caregiver-reported measures could yield a more comprehensive understanding of the biopsychosocial factors influencing growth and neurodevelopment. Standardizing developmental screening tools across cultures and languages will also improve cross-study comparability.

Although direct dietary assessments were not conducted in this pilot phase, the anthropometric indicators used – particularly WAZ and MUAC – are well-established proxies for nutritional status. The observed associations between these measures and developmental domains highlight the importance of systematic nutritional monitoring and intervention as integral components of neurodevelopmental care.

Conclusions

This pilot study demonstrates a substantial relationship between growth indicators and neuropsychological development in children with CP and ASD. The findings underscore the pivotal role of adequate nutrition and healthy growth in supporting holistic development across multiple domains. Addressing nutritional needs alongside targeted developmental interventions may improve both functional outcomes and quality of life in these populations. By building on these preliminary findings through larger, longitudinal, and intervention-focused studies, future research

can contribute to more effective, tailored care strategies for children with neurodevelopmental disorders.

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