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Serum micronutrient profiles and clinical correlates in children with cerebral palsy: A comprehensive evaluation

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ABSTRACT

Aim: The increasing prevalence of pediatric cerebral palsy (CP) underscores the critical role of micronutrients. This study aimed to investigate the relationship between clinical characteristics and micronutrient levels in CP.

Methods: In this retrospective, single-center study, data from 234 children aged 0–18 years with CP between January 2020-2025 were analyzed. Demographics, the Gross Motor Function Classification System Score (GMFCSS), comorbidities, hospitalization and pediatric intensive care unit (PICU) admissions, respiratory support, nutritional status, and infection history were evaluated. Serum levels of vitamin D, vitamin B12, folic acid, ferritin, and albumin were compared with these clinical variables.

Results: 234 children were included, with a mean age of 126.15±54.26 months. Spastic quadriplegia was the most common subtype (49.6%), and 46.6% of the cohort were classified as GMFCSS IV–V. Hospitalization history was present in 45.3%, 15.4% had PICU admission, and 64.1% experienced at least one infection in the past year. Hospitalization frequency correlated positively with vitamin B12 (r=0.194, p=0.003) and ferritin (r=0.198, p=0.002). Serum albumin was significantly lower in requiring respiratory support (p=0.016) and differed by feeding modality (p=0.031). Vitamin D levels varied only with the use of enteral nutrition products (p=0.010). Vitamin B12 levels were significantly higher in hospitalized patients, those with PICU admission, those receiving respiratory support, and users of enteral nutrition products (p<0.05).

Conclusion: The findings indicate that micronutrient status remains closely linked to clinical severity in CP. In particular, elevated vitamin B12 and ferritin correlated with higher GMFCSS, likely reflecting increased healthcare needs and supplementation practices among more severely affected.

Keywords: Cerebral palsy, vitamin B12, vitamin D, ferritin, folic acid.

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1. Introduction

Cerebral palsy (CP) refers to a heterogeneous group of permanent, non-progressive neurodevelopmental disorders arising in childhood and characterized by disturbances in posture, balance, and movement. This clinical syndrome manifests as a permanent consequence of brain damage or dysfunction [1,2]. While motor disorders may be prominent features of CP, perceptual, sensory, musculoskeletal, cognitive, learning, behavioral, communication deficits and even epileptic seizures often accompany this clinical syndrome [1-4].

Children diagnosed with CP are at increased risk of malnutrition compared with their healthy peers, primarily due to neuromotor developmental impairments. Undernutrition and malnutrition are known to adversely affect cognitive function and are associated with more severe motor dysfunction [5]. Nutritional challenges are frequent in children with CP, often necessitating support through oral supplements, nasogastric feeding, or gastrostomy to ensure adequate caloric and macronutrient intake [6-8]. Comprehensive laboratory evaluations consistently show reduced levels of key micronutrients—including iron, vitamin D, copper, magnesium, and folic acid—compared with healthy peers [9-12]. The neurocognitive effects of the drug are mediated through mechanisms involving neuroprotection, attenuation of oxidative stress, regulation of calcium homeostasis, and inhibition of inflammatory pathways [13]. Consequently, in pediatric neurology clinics where pediatric CP are monitored, both growth and developmental, and nutritional status, should be assessed at every check-up.

In pediatric neurology, the Gross Motor Function Classification System Score (GMFCSS) is widely preferred for children with cerebral palsy because it enables a standardized evaluation of usual gross motor performance, supports prognostic estimation, and improves communication in clinical follow-up and rehabilitation planning. For this purpose, GMFCSS has been defined as the most appropriate and up-to-date assessment score in literature and in practice [14,15]. The development of nutritional, vitamin and micronutrient deficiencies in CP patients is influenced by a few factors, including their neurological status, nutritional type, the presence of recurrent infections, frequency of hospitalization and pediatric intensive care unit (PICU), comorbidities, and respiratory support at home [16].

In light of the above, this study aimed to evaluate the effects of various clinical characteristics on vitamin D, ferritin, vitamin B12, and folic acid levels in pediatric patients with cerebral palsy followed up in a pediatric neurology outpatient clinic. The specific characteristics encompassed include nutritional status, disease follow-up, GMFCSS, hospital and PICU admission, the presence of comorbidity, respiratory support, and neuromotor development.

2. Materials and methods

This retrospective, single-center study was included patients aged 0–18 years who were followed in the pediatric neurology outpatient clinic with a confirmed diagnosis of CP between January 1, 2020, and January 31, 2025. The diagnosis of CP was made by pediatric neurologists based on clinical history, physical examination, and neuroimaging findings consistent with non-progressive disturbances in the developing fetal or infant brain. Patients were excluded if they met any of the following criteria: presence of congenital metabolic or genetic disorders; absence of a confirmed diagnosis of CP; unavailability of laboratory measurements for serum vitamin D, ferritin, vitamin B12, or folic acid; concurrent infection that could influence ferritin levels; or age outside the predefined range of 0–18 years.

For eligible patients, the following variables were extracted from the hospital's electronic medical record system: demographic data (age, sex), CP subtype, presence of comorbidities, nutritional status (oral vs. enteral feeding), respiratory support requirement, frequency of hospitalizations, history of admission to a PICU, frequency of infections, and GMFCSS. In addition, the following laboratory parameters recorded at the time of clinical were included: hemoglobin (Hb), leukocyte count, neutrophil count, lymphocyte count, platelet count, C-reactive protein (CRP), serum albumin, vitamin D, ferritin, vitamin B12, and folic acid levels. In this retrospective study, information on routine vitamin supplementation was not systematically available in the medical records; therefore, supplementation status could not be determined reliably. However, the patients' pediatric clinic visits were taken into consideration during the clinical evaluation.

2.1. Statistical Analysis

The analysis of the research data was conducted utilising the SPSS 27.0 statistical programme. The investigation into the conformity of continuous variables to the normal distribution was conducted utilizing both visual (histogram and probability plots) and analytical (Kolmogorov-Smirnov/Shapiro-Wilk tests) methods. The descriptive statistics of the study were presented using number (n), percentage (%), mean, standard deviation (SD), median, minimum, and maximum. The Chi-Square Test was utilised to ascertain the existence of any disparity between categorical variables in the study, whilst the Spearman Test was employed to correlate continuous variables that were not subject to parametric assumptions. Linear regression analysis was utilised when the outcome variable was numeric and its estimation required the values of one or more known variables to be considered. Statistical significance was determined by a p value of less than 0.05.

Ethical approval for this study was obtained from the Non-Interventional Clinical Research Ethics Committee of X University Faculty of Medicine (Protocol No: 2025/107, Decision No: 7), in accordance with the principles of the Declaration of Helsinki. As this was a retrospective study utilizing anonymized data from the hospital's electronic medical records, informed consent from parents or legal guardians was not required.

3. Results

Among the 234 children diagnosed with CP, 59.4% (n=139) were male and 40.6% (n=95) were female. The mean age of the cohort was 126.15 ± 54.26 months (median: 121; range: 19–221 months). The distribution of CP type was quadriplegic in 49.6% (n=116), diplegic in 39.3% (n=92), and hemiplegic in 11.1% (n=26), with spastic type predominating in 97.9% (n=229). Comorbidities were present in 13.7% (n=32). According to GMFCSS, 13.2% (n=31) were level I, 23.9% (n=56) level II, 16.2% (n=38) level III, 13.7% (n=32) level IV, and 32.9% (n=77) level V, with 53.4% (n=125) classified as levels I–III and 46.6% (n=109) as levels IV–V.

The mean number of hospital admissions was 2.72±2.41 (median 2, range 1–14); 45.3% (n=106) had a hospitalization history, with frequencies reported as none in 54.7% (n=128), PICU admission was reported in 15.4% (n=36), and infection history was present in 64.1% (n=150). Respiratory support was required in 3.8% (n=9), regarding nutrition, 81.6% (n=191) were oral feeders. Enteral nutrition products were used by 28.6% (n=67). Demographic and clinical characteristics of patients are shown in detail in Table 1.

Table 1. Demographic and clinical characteristics of the patients.

Parameters		**N (%)**
Gender	**Girl**	95(40.6)
	Boy	139(59.4)
Age (month)	**Mean±SD**	126.15±54.26
	Median (min-max)	121(19-221)
Area of CP	**Quadriplegic**	116(49.6)
	Diplegic	92(39.3)
	Hemiplegic	26(11.1)
Type of CP	**Spastic**	229(97.9)
	Dyskinetic	4(1.7)
	Mix	1(0.4)
Comorbidity	**No**	202(86.3)
	Yes	32(13.7)
Type of comorbidities	**Renal diseases**	14(43.8)
	Endocrinological diseases	9(28.1)
	Cardiac diseases	6(18.8)
	Hematological diseases	1(3.1)
	Gastrointestinal system diseases	1(3.1)
	Respiratory diseases	1(3.1)
GMFCSS	**I**	31(13.2)
	II	56(23.9)
	III	38(16.2)
	IV	32(13.7)
	V	77(32.9)
GMFCSS	**I-III**	125(53.4)
	IV-V	109(46.6)
Number of hospital admissions	**Mean±SD**	2.72±2.41
	Median(min-max)	2(1-14)
Hospitalization history	**No**	128(54.7)
	Yes	106(45.3)
Frequency of hospitalization	**No**	128(54.7)
	1-2 times a year	81(34.6)
	3-4 times a year	24(10.3)
	Every month	1(0.4)
Presence of PICU admission	**No**	198(84.6)
	Yes	36(15.4)
Infection history	**No**	84(35.9)
	Yes	150(64.1)
Infection frequency	**No**	84(35.9)
	1-2 times a year	131(56.0)
	3-4 times a year	18(7.7)
	Every month	1(0.4)

Respiratory support	**No**	225(96.2)
	Yes	9(3.8)
Type of respiratory support	**Room air**	225(96.2)
	Oxygen support with nasal cannula at home	4(1.7)
	Spontaneous breathing with tracheostomy	4(1.7)
	Home-type MV support with tracheostomy	1(0.4)
Nutrition method	**Oral**	191(81.6)
	Nasogastric tube	39(16.7)
	Gastrostomy	4(1.7)
Use of enteral nutrition products	**No**	167(71.4)
	Yes	67(28.6)

SD: *Standart deviation****;*** ***CP:*** *Cerebral palsi****;*** ***GMFCSS:*** *Gross Motor Function Classification System Score****;*** ***PICU:*** *Pediatric intensive care unit****;*** ***MV:*** *Mechanical ventilation*

Laboratory analysis of the patients included in the study is demonstrated in Table 2, showing complete blood count parameters, CRP, and serum albumin levels. The mean hemoglobin was 12.50±1.44 g/dL, with white blood cell (WBC) 8784.90±2846.90 (10^3/µL), neutrophils 4551.62±2427.34 (10^3/µL), lymphocytes 3175.21±1465.25 (10^3/µL), and platelets 277102.56±95420.50 (10^3/µL). CRP was 2.92±3.56 mg/L. Albumin averaged 40.13±4.87 g/L, with 5.1% (n=12) of patients <3.5 g/L and 94.9% (n=222) ≥3.5 g/L. Vitamin B12 was 553.30±341.03 pg/mL; 6.0% (n=14) had <200 pg/mL, 11.5% (n=27) between 200–300 pg/mL, and 82.5% (n=193) >300 pg/mL. Folic acid was 9.92±3.96 ng/mL. Vitamin D was 23.83±12.85 ng/mL, with 44.9% (n=105) <20 ng/mL, 27.4% (n=64) between 20–30 ng/mL, and 27.8% (n=65) >30 ng/mL. Ferritin was 50.97±179.41 ng/mL. The relationship between the number of hospital admissions and GMFCSS with vitamin B12, folic acid, vitamin D and ferritin levels: Vitamin B12 (r=0.194, *p*=0.003) and ferritin (r=0.198, *p*=0.002) showed a positive correlation with hospitalization frequency. Folic acid (r=-0.035, *p*=0.597) and vitamin D had a no significant correlation (r=0.017, *p*=0.793).

The relationship between serum albumin, vitamin D, and vitamin B12 levels and clinical status: Evaluation of serum albumin demonstrated a significant difference between groups: the median level was 37 g/dL (21.8–42) in patients requiring respiratory support compared with 40 g/dL (4.2–51) in those not receiving support (*p* = 0.016). Albumin levels also varied significantly by feeding modality, with median values of 40 g/dL (4.2–49.2) in orally fed patients, 38.6 g/dL (21.8–51) in those receiving nasogastric feeding, and 39.5 g/dL (37–41) in gastrostomy-fed patients (*p* = 0.031). For vitamin D, a significant difference was observed only in relation to the use of enteral nutrition products; the median level was 20 ng/mL (4–92) in non-users and 25 ng/mL (6–55) in users (*p* = 0.010). Vitamin B12 levels showed significant associations with multiple clinical parameters and its concentrations were higher in hospitalized versus non-hospitalized patients (531 pg/mL [43–2000] vs. 419 pg/mL [112–1455], *p* = 0.003), in those with versus without PICU admission (680 pg/mL [172–2000] vs. 443 pg/mL [43–1632], p = 0.002), in patients receiving respiratory support compared with those who did not (825 pg/mL [219–2000] vs. 460 pg/mL [43–2000], *p* = 0.048), and in enteral product users versus non-users (609 pg/mL [43–2000] vs. 429 pg/mL [112–2000], *p* = 0.001). These findings are shown in detail in Table 3 and Table 4.

Table 2. Laboratory analysis of the patients included in the study.

Parameters		
Hb (gr/dL)	Mean±SD	12.50±1.44
	Median(min-max)	12.6(7.8-16)
WBC (10^3/µL)	Mean±SD	8784.09±2846.90
	Median(min-max)	8455(80.7-19860)
Neutrophil (10^3/µL)	Mean±SD	4551.62±2427.34
	Median(min-max)	4200(760-16100)
Lymphocyte (10^3/µL)	Mean±SD	3175.21±1465.25
	Median(min-max)	2785(770-7700)
Plateles (10^3/µL)	Mean±SD	277102.56±95420.50
	Median(min-max)	257500(44000-752000)
CRP (mg/L)	Mean±SD	2.92±3.56
	Median(min-max)	2(0.27-33)
Albumin (g/L)	Mean±SD	40.13±4.87
	Median(min-max)	40(4.2-51)
Albumin level groups	<3,5 g/L	12(5.1)
	≥3,5 g/L	222(94.9)
Vitamin B12 (pg/mL)	Mean±SD	553.30±341.03
	Median(min-max)	463.5(42.7-2000)
Vitamin B12 level groups	<200 pg/mL	14(6.0)
	200-300 pg/mL	27(11.5)
	>300 pg/mL	193(82.5)
Folic acid (ng/mL)	Mean±SD	9.92±3.96
	Median(min-max)	9.75(2.9-20)
Vitamin D (ng/mL)	Mean±SD	23.83±12.85
	Median(min-max)	22(3.8-92)
Vitamin D level groups	<20 ng/mL	105(44.9)
	20-30 ng/mL	64(27.4)
	>30 ng/mL	65(27.8)
Ferritin (ng/mL)	Mean±SD	50.97±179.41
	Median(min-max)	21.95(2.94-2160)

Hb: Hemoglobin; SD: Standart deviation; WBC: White blood cell; CRP: C-reactive protein

Table 3. The relationship between the number of hospital admissions with vitamin B12, folic acid, vitamin D and ferritin levels.

Parameters		**Frequency of hospitalization**
Vitamin B12	**r**	0.194
	p	**0.003***
Folic acid	**r**	-0.035
	p	0.597*
Vitamin D	**r**	0.017
	p	0.793*
Ferritin	**r**	0.198
	p	**0.002***

A p value below 0.05 was considered significant.
** Spearman correlation test*

In the comparison of laboratory parameters according to GMFCS score, children in levels I–III had a hemoglobin level of 12.72±1.23 g/dL, whereas those in levels IV–V had 12.25±1.63 g/dL (p=0.016). Albumin was 40.85±4.17 g/L in GMFCSS I–III and 39.30±5.47 g/L in GMFCSS IV–V (p=0.059, borderline significance). Vitamin B12 levels were significantly lower in GMFCSS I–III with 480.35±284.06 pg/mL compared to 636.95±380.86 pg/mL in GMFCSS IV–V (p<0.001) (Table 5).

Table 4. The relationship between serum albumin, vitamin D and vitamin B12 levels and clinical status.

Parameters		Serum albumin levels		p	Vitamin D Levels		p	Vitamin B12 levels		p
		Ort±SS	Ortanca (min-maks)		Ort±SS	Ortanca (min-maks)		Ort±SS	Ortanca (min-maks)	
Hospitalization history										
	No	40.78±3.98	40 (30-49)	0.074*	22.25±10.63	20 (6-63)	0.134*	483.64±249.47	419 (112-1455)	**0.003***
	Yes	39.33±5.69	40 (4.2-51)		25.75±14.93	23 (4-92)		637.41±412.01	531 (43-2000)	
Frequency of hospitalization										
	1-2 times a year	39.63±5.52	40 (4.2-51)	0.523*	26.50±14.89	24 (4-92)	0.197*	593.31±329.29	534 (145-1632)	0.299*
	>2 times a year	38.37±6.22	40 (21.8-48)		23.33±15.13	18 (8-66)		780.31±594.46	494 (43-2000)	
Infection history										
	No	40.49±3.79	40 (30-48)	0.838*	22.62±12.11	20 (6-63)	0.244*	491.77±260.09	429 (112-1554)	0.068*
	Yes	39.92±5.38	40 (4.2-51)		24.51±13.24	22 (4-92)		587.75±375.32	488 (43-2000)	
Infection frequency										
	1-2 times a year	40.20±5.19	40 (4.2-51)	0.152*	24.47±13.35	22 (4-92)	0.876*	579.10±355.11	489 (141-2000)	0.758*
	>2 times a year	38.05±6.38	39 (22-49.2)		24.83±12.77	22 (9-51)		647.41±500.97	486 (43-2000)	
Presence of PICU admission										
	No	40.39±4.65	40 (4.2-51)	0.204*	23.65±12.85	22 (4-92)	0.555*	515.97±290.43	443 (43-1632)	**0.002***
	Yes	38.66±5.80	40 (21.8-48)		24.84±13.01	22 (6-66)		758.58±498.26	680 (172-2000)	
Respiratory Support										
	No	40.28±4.77	40 (4.2-51)	**0.016***	23.65±12.85	22 (4-92)	0.229*	539.43±320.09	460(43-2000)	**0.048***
	Yes	36.20±6.03	37 (21.8-42)		28.31±12.84	32 (10-48)		899.89±614.77	825 (219-2000)	
Nutrition method										
	Oral	40.53±4.68	40 (4.2-49.2)	**0.038[1]***	23.19±12.86	22 (4-92)	0.149*	526.81±307.91	444 (112-2000)	0.019*
	Nasogastric tube	38.25±5.59	38.6 (21.8-51)		26.15±12.17	23 (8-55)		636.74±429.36	494 (43-2000)	
	Gastrostomy	39.25±1.71	39.5 (37-41)		32.13±17.10	32 (12-53)		1004.75±535.33	855 (539-1771)	
Use of enteral nutrition products										
	No	40.63±3.95	40 (30-49.2)	0.144*	22.75±12.97	20 (4-92)	**0.010***	500.11±284.77	429 (112-2000)	**0.001***
	Yes	38.87±6.49	40 (4.2-51)		26.55±12.23	25 (6-55)		685.88±426.17	609 (43-2000)	

**Non parametric test. PICU: Pediatric intensive care unit. A p value below 0.05 was considered significant.*

Table 5. Comparison of laboratory parameters according to GMFCSS score.

Parameters	GMFCSS				p
	Level I-III		Level IV-V		
	Mean±SD	Median(Min-Max)	Mean±SD	Median(Min-Max)	
Albumin	40.85±4.17	40 (30-49.2)	39.30±5.47	40 (4.2-51)	0.059**
Vitamin B12	480.35±284.06	410 (112-2000)	636.95±380.86	527 (42.7-2000)	**<0.001****
Folic acid	9.62±3.77	9.5 (2.9-20)	10.27±4.16	10 (3.1-20)	0.335**
Vitamin D	23.46±13.72	22 (3.8-92)	24.27±11.82	22 (5.8-63.1)	0.335**
Ferritin	26.15±20.14	20.6 (3.2-124)	79.42±259.71	24 (2.9-2160)	0.102**

*GMFCSS: Gross Motor Function Classification System Score. *Parametric test **Nonparametric test*

4. Discussion

This study demonstrated that micronutrient status in children with CP is closely associated with markers of clinical severity and medical complexity. In particular, elevated vitamin B12 and ferritin levels with higher GMFCSS levels, more frequent hospitalization, PICU admission, respiratory support, and enteral nutrition use suggest that these biochemical findings may reflect not only disease burden itself but also greater healthcare contact and supplementation practices in more severely affected children.

Cerebral palsy is defined as a group of permanent but not unchanging disorders of movement, posture, and motor function resulting from a non-progressive disturbance or injury to the developing brain. The mean incidence of CP is approximated at between 1.5 and 3.0 per 1000 live births [17-20]. CP can be classified based on motor type, anatomical distribution, and severity, with Ingram's and Hagberg's systems encompassing spastic, dyskinetic, ataxic, and mixed forms as well as diplegic, hemiplegic, and tetraplegic involvement [21,22]. Among these, spastic CP is the most prevalent, accounting for nearly 80% of all cases [23]. Similar to the literature, in our single-centre retrospective study, conducted in a tertiary university hospital, 27% of all 3626 pediatric outpatient clinic visits over a 5-year period consisted of 980 patients who presented to the pediatric neurology outpatient clinic, and 314 (6.5%) were diagnosed with CP. Amongst patients diagnosed with CP, the most prevalent region was quadriplegic (49.6%), and the most common type was spastic CP (97.9%).

In a study of 100 CP patients over a 1-year period, it was found that spastic CP was the most common type (72.5%), consistent with previous reports. Among the various subtypes of spastic paraplegia, diplegia was the most prevalent, suggesting a significant role for prenatal and perinatal factors. The most prevalent comorbidity was cognitive impairment (77%), followed by epilepsy and sensory deficits [24]. A further study was conducted, the focus of which was to examine a cohort of CP patients over a period of four years in India. The study included a total of 384 patients. In this study, the most prevalent etiology for CP comorbidity was identified as birth-related factors, accounting for 83.3% of cases [25]. In this study, similarly, the distribution of CP type was mostly quadriplegic in 49.6% and diplegic in 39.3%, with spastic type predominating in 97.9%. Comorbidities were present in 13.7%, most frequently renal diseases 43.8%.

A study of a seven-year duration was conducted to examine hospital admissions from CP records in Victoria, Australia. The study in question examined 1748 CP admissions. The analysis revealed that 80% of the CP cohort had at least one admission to hospital, accounting for 11012 hospital admissions, which represented 1.5% of all admissions in the same age group. Increasing severity and complexity of CP have been demonstrated to be associated with a higher number of hospital admissions and a higher proportion of admissions due to respiratory illness [26]. In our study, 45.3% of the CP patients examined had a history of hospitalisation. Furthermore, a total of 15.4% of the patients were also admitted to the PICU. Moreover, 64.1% of patients had a history of infection, with 56% of these patients admitting at least one or two infections per year. These elevated rates are indicative of the finding in the extant literature that CP patients in our study significantly increase hospitalization rates and, consequently, healthcare costs. A significant proportion of children diagnosed with CP encounter difficulties with regard to feeding and gastrointestinal disorders, including oropharyngeal dysfunction, gastroesophageal disease, and constipation [27-28]. Therefore, patient-specific enteral nutrition solutions are employed to address the nutritional challenges experienced by patients with CP. The utilisation of these solutions orally, via nasogastric or gastrostomy tube, constitutes a pivotal step in the prevention of growth and developmental issues, as well as malnutrition [29,30].

Respiratory illness with CP is a multifactorial condition primarily driven by chronic aspiration and impaired airway clearance, often resembling respiratory complications seen in neuromuscular disorders. Studies have shown a high prevalence of respiratory symptoms among individuals with CP, particularly in those classified as GMFCS levels IV and V [31-34]. According to GMFCS with 53.4% classified as levels I–III and 46.6% as levels IV–V. As stated above, in this study, most patients had mild-moderate motor functions according to the GMFCSS, the necessity for respiratory support, encompassing home oxygen therapy, tracheostomy with spontaneous breathing, and mechanical ventilation, was observed to vary depending on the specific circumstances. In the context of the present study, 3.8% of patients exhibited a requirement for such respiratory support. While most of these patients (81.6%) were orally fed, 18.4% received enteral nutrition via nasogastric tube or gastrostomy, highlighting the prevalence of feeding difficulties in this population. These results demonstrate the effects of neurological disorders on both feeding/swallowing and respiration.

A 2016 retrospective study involving 172 pediatric CP patients demonstrated a significant reduction in serum albumin levels among those with GI complications—such as constipation, esophagitis, and feeding difficulties—compared to those without [35]. In this study, mild and moderate in the majority, while a smaller number were fed via nasogastric tube (16.7%) and gastrostomy (1.7%). Enteral nutrition was utilized in 28.6% of patients. Contrary to the findings reported in the extant literature, the mean serum albumin level was determined to be 40.13±4.87 g/L, with 94.9% of the population demonstrating serum albumin levels of at least 3.5 g/L.

Feeding difficulties in children with CP tend to increase with the severity of motor impairment and are strongly associated with nutritional deficiencies [36,37]. Consistent with earlier findings, this study showed that 44.9% of patients had vitamin D levels below 20 ng/mL, indicating a high prevalence of deficiency among CP. A recent study conducted in our country and published in 2025 aimed to determine the prevalence of vitamin D deficiency in children and identify associated risk factors. In this study, vitamin D levels of 35,620 healthy children were retrospectively analyzed according to demographic data. The mean serum vitamin D level in the study was 21±12.37 ng/mL, and 54.7% of the included children had high vitamin D levels ≤ 20 ng/mL, as in our study [38].

In a 2023 study conducted in our country, 117 patients were examined and their micronutrient levels were compared, including children with CP and a healthy control group. The study found that vitamin D levels were significantly low and vitamin B12 levels were significantly high in patients with CP. Furthermore, folic acid and ferritin levels were found to be similar to those in our study [39]. In this study, similarly, vitamin B12 was 553.30±341.03 pg/mL; folic acid was 9.92±3.96 ng/mL; Vitamin D was 23.83±12.85 ng/mL; ferritin was 50.97±179.41 ng/mL. Ferritin is an acute-phase reactant and may be affected not only by infection but also by underlying inflammatory conditions. Although patients with concurrent infection were excluded from the study, the potential influence of subclinical or non-infectious inflammatory processes on ferritin levels should be considered when interpreting the findings [40].

A 4-year study of 274 children diagnosed with CP was conducted, in which vitamin D levels were compared with GMFCSS and Manual Ability Classification System (MACS) scores. A significant correlation was identified between 25(OH)D levels, GMFCSS and MACS levels, and associated disorders such as history of epilepsy, mental retardation, dental problems, and growth retardation [41]. In this study, serum albumin, vitamin D, and vitamin B12 levels demonstrated notable associations with clinical status. Lower albumin levels were observed in patients requiring respiratory support and in those dependent on nasogastric feeding, suggesting that nutritional status and disease severity may contribute to hypoalbuminemia. Vitamin D levels differed only using enteral nutrition products, indicating that supplementation through fortified formulas may influence vitamin D status more than clinical severity itself. Interestingly, vitamin B12 concentrations were significantly higher in patients with greater clinical burden, including those who were hospitalized, admitted to PICU, receiving respiratory support, or using enteral products—likely reflecting increased supplementation practices rather than improved nutritional status. Together, these findings underscore the complex interplay between micronutrient levels, nutrition practices, and disease severity in children with CP. A significant positive correlation was also observed between vitamin B12 levels and both ferritin concentrations and the number of hospital admissions, suggesting that elevated vitamin B12 may reflect greater disease severity, increased healthcare utilization, or more frequent nutritional supplementation in this population.

A multicenter, comprehensive study conducted in our country examined albumin levels at the time of admission in critically ill in PICUs. The findings of the study indicated that serum albumin levels can serve as a reliable indicator of mortality and outcomes. It has also been reported as a means of predicting the necessity for treatment and mechanical support

[42]. In this study, serum albumin and vitamin B12 levels were found to be statistically significantly higher in the GMFCSS IV-V group. This was associated with an increase in healthcare visits in the high GMFCSS group, and consequently, an increase in patient compliance with care, nutrition, and supportive treatments. Additionally, low albumin levels were significantly the need for respiratory support, indicating its potential role as a marker of disease severity. A study from our own country arrived at a similar conclusion, finding higher vitamin B12 levels in patients with CP compared to the healthy control group. The study noted that the underlying pathophysiology was not clear but suggested that it may be related to environmental factors [28]. Consistent with our findings, in a 2020 study conducted in the same region of our country, the nutritional patterns and nutritional status of 59 pediatric patients with CP were evaluated, with analyses including demographic characteristics, CP type, GMFCSS level, anthropometric measurements, comorbidities, feeding method, and micronutrient parameters. Malnutrition was found to be significantly more common in patients with spastic quadriplegic CP and in those classified as GMFCSS level V. Furthermore, serum iron, ferritin, vitamin B12, and folate levels were reported to be low only in patients receiving oral feeding [43].

Despite the limitations of our retrospective study, which included patients with CP at a single centre over a 5-year period and followed the same treatment procedures by the same physician group, our findings offer valuable insights. The study's limitations include the lack of a standardized number of examinations, the absence of information on family vitamin supplement use, and the lack of periodic vitamin level monitoring. In order to obtain more definitive data, multicenter, prospective studies utilizing standardized treatment protocols are required.

In conclusion, vitamin B12 and ferritin levels were found to be elevated in pediatric patients with CP and were associated with GMFCSS level. These findings may reflect differences related not only to clinical severity but also to healthcare contact and micronutrient supplementation. Therefore, regular nutritional assessment and careful monitoring of micronutrient status may contribute to improved individualized care in children with CP.

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