Research progress regarding the nutritional status and assessment methods of cerebral palsy patients

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Abstract
Cerebral palsy is a group of clinical disorders characterized by persistent central motor deficits and postural abnormalities due to non-progressive damage to the fetal or infant brain. Malnutrition is one of the most common clinical comorbidities in children with cerebral palsy and is the result of a combination of internal factors, such as the child’s structural and functional abnormalities, and external factors, such as the child’s feeding habits and family/social factors. The nutritional status of children with cerebral palsy is closely related to their development, quality of life, social participation, and life expectancy; thus, an objective and accurate understanding of the nutritional status of these children through rehabilitation assessment is essential for their growth and development. The current nutritional assessments include routine measurements of human nutritional parameters, scale-based assessments, and instrumental assessments. It is important to detect malnutrition in children with cerebral palsy at an early stage, reduce the prevalence of malnutrition, and improve the quality of survival. Therefore, this review aimed to analyze and summarize the nutritional status and assessment methods of children with cerebral palsy, to assess the nutritional status of children with cerebral palsy from multiple perspectives, indicators and directions, and to provide reference for the early detection of co-morbid malnutrition in children with cerebral palsy.

Keywords: children with cerebral palsy; nutritional status; evaluation method

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**Introduction**

Cerebral palsy (CP) occurs due to non-progressive damage to the foetus or infant brain caused by the persistent central motor and postural development disorders, leading to activity limitations, and is frequently accompanied by speech, language, cognitive, and communication and behaviour disorders. The incidence of CP is approximately 2%, and that in China is approximately 2.46/10,000. The incidence of CP in infants with birth weight less than 1500 gm is 70 times higher than that in infants with birth weight more than 2500 gm [1, 2]. Malnutrition in children with CP is caused by reduced food intake and absorption due to factors such as damage to the central nervous system, irregular feeding, and the disease itself. Nutritional abnormalities can adversely affect the growth and development, disease prognosis, and life expectancy of children with CP in various ways. This study reviewed the nutritional status of children with CP and its assessment methods, analysed the factors contributing to malnutrition in them, and summarised the commonly used nutrition-assessment methods to provide a reference for early clinical detection of malnutrition.

**Nutritional profile of children with cerebral palsy**

Nutrition is an essential factor for ensuring normal growth and development as well as the physical and mental health of children, and the nutritional status of a child reflects the health status. With the ongoing research on CP, the co-occurrence of malnutrition in children with CP has become a prominent clinical issue. Malnutrition is a nutritional disease that occurs when the protein and energy intake is insufficient, overconsumed, or not reabsorbed adequately to meet the growth, development, and physiological needs. Long-term malnutrition not only affects the children's growth and development gravely but also their physical and mental health. This study showed that the overall prevalence of malnutrition in children with CP was 40% [3], while that in Turkey, Indonesia, and Nepal was 57.2%, 78.8%, and 51.7%, respectively [4–6]. Li et al. reported a prevalence of 55.7% [7]. Malnutrition in children with CP manifests primarily as underweight and delayed development, which constrain each other, severely affecting the child's overall development and gradually affecting the child's daily living ability and quality of life. Therefore, malnutrition is a crucial clinical issue in rehabilitating children with CP.

**Causes of malnutrition in children with cerebral palsy**

**Internal causes**

**Structural and functional abnormalities.** Nutrient intake, digestion, and absorption comprise a complex process; hence, the structure and function of the digestive system can influence an individual's nutrient intake. Swallowing is an essential activity in the human body for nutrient intake. The mouth, larynx, and oesophagus are involved in the process of swallowing, and the completion of the swallowing action depends on the dynamic integration of the sensory and muscular activities as well as coordinated movements of the cheeks, tongue, palate, pharynx, hyoid bone, and larynx. The abnormal posture of children with CP, such as abnormal head position, scapular retraction, and anterior tilting of the pelvis, affects the oropharyngeal position, restricts swallowing activities, and impedes the swallowing and flow of food, thus affecting food intake [8]. Furthermore, facial deformities, poorly aligned teeth, retraction of the upper lip, incomplete lip closure, and poor oral hygiene in children with CP, an prolong the time the food is retained in the mouth, resulting in an increased incidence of dental caries and long-term negative effects on their nutritional intake [9–11]. In addition, damage to their central nervous system can lead to abnormal neuromuscular regulation, dysphagia, dyspraxia of the lower oesophageal sphincter, and dysphagia of the oesophageal peristalsis, leading to gastro-oesophageal reflux, which can be exacerbated by scoliosis and epilepsy.

Agarshrizari et al. [12] found that the prevalence rates of swallowing disorder and gastro-oesophageal reflux disease in children with CP were 82% and 66%, respectively. Some of them experience dyskinnesia due to skeletal muscle coordination, skeletal malformations, movement disorders, intestinal disorders, monophasic diets, insufficient fibre intake, constipation due to anti-seizure medications, and indirect causes of gastro-oesophageal reflux that additionally affect the digestion and absorption of gastrointestinal nutrients, thus exacerbating malnutrition.

**Other influencing factors**

Sex, age, clinical type of CP, and malnutrition in children with CP show a correlation of varying degrees. The prevalence of anaemia in children with CP is sex-specific. The prevalence of anaemia is six times higher in males than in females, and males are more prone to iron and zinc deficiency than females [13]. The intake of protein, calcium, and riboflavin was lower in females than in males, but no significant sex-related differences were found in the levels of haemoglobin, vitamin A, alpha-tocopherol, copper, and magnesium among children with CP. The overall nutritional status of children with CP changes with age. The proportion of children presenting underweight and developmental delay is higher among those aged 5–10 years than among those aged 0–5 years. Moreover, the deficiency of nutrients, such as protein, vitamins, calcium, and iron, is more severe in children aged over 5 years than in those aged below 5 years [14]. The incidence of malnutrition is higher in children with spastic paralysis than in those with the other clinical subtypes of CP. Malnutrition is the most severe in children with spastic trim/quadruplegic paralysis, which may be closely associated with restricted oral movements and swallowing difficulties [15].

**External causes**

**Feeding and care.** Speyer et al. [16, 17] found that 53.5% of children with CP had feeding problems, and the incidence of feeding problems increased with the worsening of gross motor disorders. The main factors causing feeding problems in these children include structural abnormalities and dysfunction, inability to chew, digest, and absorb food effectively, and inability to express hunger or fullness accurately. From the caregiver's point of view, the main concerns considering the feeding problem are the timely detection of abnormal food intake, digestion, and absorption and whether the appropriate intake of nutrients and food texture are adequately defined.

Children with CP should avoid foods that are tough and have elevated sugar content to reduce the incidence of dental caries. Children with involuntary sports CP should be given foods with slightly higher viscosity for easy swallowing, while those with spasticity and ataxia should be given soft, smooth, homogenous, and easy-to-chew foods [18]. Although current research suggests that the total duration of meals for children with CP should not exceed 3–4 hours, the optimal frequency of meals has not been definitively reported. Proper body positioning can improve feeding efficiency. The optimal feeding position for a child with CP with dysphagia is maintaining a centred head, neck flexed slightly forward, and trunk perpendicular to the ground; for a young child or one with an unstable upright head, a holding feeding position is preferred. Moreover, appropriate cutlery use can increase the efficiency of eating. Typically, a flat spoon with a high handle is chosen. A moderate amount of water should be given from the corner of the mouth before feeding to assess swallowing. Special attention should be given to emotional guidance during meals, and the use of soothing music, adding fun games, and other methods should be considered. Particularly, caregivers should be patient, avoid overlapping food, and be vigilant about coughing reflexes. They should pay attention to nutrition and record the child’s dietary habits such as eating times, food type and quantity, and instances of choking and coughing. Additionally, they should observe the child's complications, changes in food intake, diarrhoea (≥ 5 times/day), and vomiting (≥ 3 times/day). Studies have shown that nutritional guidance for caregivers can help improve the nutritional status of children with CP to some extent [19].

**Other influencing factors**
Children with CP are indirectly affected by regional economic conditions, parental education levels, social status, and family economic status. The prevalence of malnutrition in children with CP is higher in low- and middle-income countries than in high-income countries. The other factors affecting the nutritional status include poor economic status, food shortages, inadequate knowledge of caregivers, and inadequate medical resources. Studies have found that moderate to severe malnutrition (underweight and stunting) correlates significantly with monthly family income. The higher the education level of parents, the more attention paid to the children with CP, and thus lower is the prevalence of malnutrition [20].

Methods for assessing nutritional status

General nutritional status assessment indicators include skin fold thickness, upper arm circumference (UAC), height, weight, and body mass index. Measurement of the thickness of the skin folds includes measuring the upper arm triceps, subscapularis, and suprailiac, with the values reflecting the subcutaneous fat content of the limbs, trunk and waist, and abdomen, respectively. The UAC reflects the nutritional status of the patient, and its value significantly correlates with body weight. In our country, malnourishment is indicated if common children aged 1–5 years have a UAC < 12.5 cm; medium nutrition if UAC is 12.5–13.5 cm; and excellent nutrition if UAC is > 13.5 cm. The height of children aged 0–2 years is measured using a length measurement bed, whereas the height measurement apparatus is for the upright measurements of children aged > 2 years. For patients with severe contracture, spasm, scoliosis, or incoordination, the knee height is used to estimate the body length. The knee height is measured with the knee and ankle joints in the 90° position and by measuring the distance between the proximal end of the patella and the heel; in hemiplegia patients, the normal side of the lower limb is chosen for measurement. The European Society for Paediatric Gastroenterology Hepatology and Nutrition guidelines suggest that knee height can be used as an effective substitute for height in children with neurological disorders, such as arthrogryposis and skeletal deformities [21]. Measures assessing the general nutritional status are simple and readily available. To ensure the standard and reliability of the data, the specific details of the data measurements should be strengthened and an average of the three measurements should be used as the final data.

Scale evaluation and instrument use

Child malnutrition risk screening tools

The Screening Tool for the Assessment of Malnutrition in Paediatrics (STAMP) is a concise, objective, and convenient assessment method that includes anthropometric measurements, the child’s diet, and clinical procedures, and it was proposed by McCarthy, et al. in 2008 for children aged 2–17 years only [22]. The Paediatric Yorkhill Malnutrition Score (PYMS) is a nutritional screening scale that includes the child’s recent weight, diet, and disease status itself, as proposed by Gerasimidis, et al. in 2010; however, it requires the use of growth curves or percentile charts, and its sensitivity and specificity are low. The Screening Tool for Nutritional Status and Growth Risk (STRONGkids), proposed by Hurst, et al. in 2010, is an assessment method that includes the following four aspects: subjective global assessment (SGA), high-risk diseases, nutritional intake and loss, and recent weight gain or loss. It is relatively easy to use, as it does not include anthropometric and biochemical indicators [23]. However, the subjective and comprehensive assessment, the wide range of high-risk diseases covered, and the lack of uniform criteria for its generalizability warrant additional research. A European multicentre study found a stronger association between STRONGkids and length of hospital stay in children than that between STAMP and PYMS and length of hospital stay. A single-centre study in China showed that both STRONGkids and PYMS can be used to screen for nutritional risk in children with critical illnesses; although STRONGkids has the highest sensitivity, its applicability in children with critical illnesses needs further validation [24].

The Paediatric Nutrition Screening Tool (PNST), developed by Melinda W, et al. in 2016 for hospitalised children, does not include anthropometric assessments, complicated scoring systems, or disease status. Instead, it consists of four simple ‘yes/no’ questions about the family’s experiences and perceptions of the feeding status of the child. Although PNST is a sensitive, simple, and effective screening tool for all age groups and all clinical diagnoses, it has limitations in screening overweight and obese children. A recent prospective study showed that the PNST is more effective than the STRONGkids and that it is based on the SGA for nutritional screening.

The Electronic Health Records-Pediatric Malnutrition Assessment Screening Tool (EHR-STAMP) electronic health record is a nutritional screening tool for hospitalised children, which incorporates the Institute of Enteral and Parenteral Nutrition’s paediatric malnutrition indicators into the assessment criteria (Table 1).

Child malnutrition assessment tool

The SGA is a nutritional assessment tool proposed by Serker and Jeejeebhoy in 2007. The tool is based on the SGA for adults and covers feeding, gastrointestinal function, and anthropometric indicators, and it is useful for assessing nutrition-related complications in children and predicting the length of hospital stay [24]. It opposes the use of single anthropometric indicators to assess the children’s nutritional status [25] and is reproducible and stable in the short term to identify malnutrition in children with CP [26]. SGA provides a clinically useful multidimensional nutritional assessment method for children with CP; however, there is no standardised scoring system, and it is not suitable for general dissemination, as it is complex and requires professional involvement. Ong, et al. [25] suggested the use of SGA as an adjunct to age/weight Z-scores for assessing the nutritional status of patients with developmental disabilities. Health care Worker toolkit database [27] suggested the development of a healthcare provider toolkit database containing height, weight, and caregiver approaches to manage feeding difficulties in children with CP and assist in assessing their nutritional status.

The Oral Motor Assessment Scale is economical, simple, and reliable and is widely used overseas for the nutritional assessment of children with CP. The Dysphagia questionnaire, Pre-Speech Assessment Scale, and Oral Motor Assessment Scale were used to determine the swallowing function. The Oral Motor Assessment Scale showed high specificity and low sensitivity, while the other two showed high sensitivity and low specificity.

The World Health Organization (WHO) developed WHO Anthro for children aged ≤ 5 years), which is a growth assessment software that is based on data from 8,000 children aged 0–5 years worldwide with different feeding practices to help users measure the current development of the children. The WHO AnthroPlus software is designed to measure growth in school-age children and adolescents from the age of 5 years. The test contains anthropometric calculations, individual assessments, and nutritional surveys to determine the child’s current developmental status and to provide timely and appropriate interventions (Table 2).

Use of instruments

Bioelectrical impedance analysis, dual-energy X-ray absorptiometry, and biochemical tests are objective tools used for assessing the nutritional status of children with CP. Although dual-energy X-ray absorptiometry is also used to evaluate body composition, it requires specialisation equipment and is time-consuming and costly, thus making it difficult for widespread use. Moreover, the reproducibility of its results is not easy. Biochemical tests, including blood analysis, albumin determination, and quantification of trace elements, are limited in their clinical application due to poor cooperation of the child and the family and the number of evaluations required.

Thus, the nutritional assessment of children with CP is challenging, and clinical assessment is based on a multimodal approach, where the body mass index and height/weight and height/age Z-scores are used as the basis for assessment [28]. Currently, the age/weight Z-score is
Table 1 List of tools for screening children for malnutrition risk

<table>
<thead>
<tr>
<th>Name</th>
<th>Developer</th>
<th>Development time</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAMP</td>
<td>McCarthy</td>
<td>2008</td>
<td>Simple, objective and convenient</td>
<td>Children 2–17 years old</td>
</tr>
<tr>
<td>PYMS</td>
<td>Gerasimidis</td>
<td>2010</td>
<td>Recent weight, diet, disease condition</td>
<td>Low sensitivity and specificity; no underlying diseases or drugs were involved.</td>
</tr>
<tr>
<td>STRONGkids</td>
<td>Hulst</td>
<td>2010</td>
<td>High caregiver compliance and predicted hospital outcomes</td>
<td>Complex, no uniform standards</td>
</tr>
<tr>
<td>PNST</td>
<td>Melinda.W</td>
<td>2016</td>
<td>Wide range of application</td>
<td>In addition to overweight, obese children</td>
</tr>
<tr>
<td>EHR</td>
<td></td>
<td>2018</td>
<td>Reliability and specificity can be used</td>
<td>High cost</td>
</tr>
</tbody>
</table>

STAMP, Pediatric Malnutrition assessment screening tool; PYMS, Pediatric Yorkhill malnutrition score; STRONGkids, Nutritional Status and growth risk screening tool; PNST, Pediatric Nutrition Screening tool; EHR, Electronic Health Records-Pediatric Malnutrition Assessment Screening tool.

Table 2 List of child malnutrition assessment tools

<table>
<thead>
<tr>
<th>Name</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGNA</td>
<td>Assessment of nutrition-related complications and estimated length of stay in children; Good repeatability and short-term stability</td>
<td>There is no standardized system, the operation is complex, and the participation of professionals is required.</td>
</tr>
<tr>
<td>Health care worker toolkit database</td>
<td>Address the caregiver’s feeding difficulties</td>
<td></td>
</tr>
<tr>
<td>Evaluation of oral movement disorders</td>
<td>Low cost, simple and reliable</td>
<td></td>
</tr>
<tr>
<td>WHO Anthro</td>
<td>Suitable for children up to 5 years old</td>
<td></td>
</tr>
<tr>
<td>WHO AnthroPlus</td>
<td>Suitable for preschoolers and teenagers over 5 years old</td>
<td></td>
</tr>
</tbody>
</table>

SGNA, Subjective Global Nutrition Assessment; WHO, World Health Organization.

commonly used in clinical practice to assess the overall nutritional status of children with CP, whereas the height/weight Z-score and height/age Z-score measure acute and chronic malnutrition, respectively. The height/age Z-score is the most sensitive anthropometric parameter for assessing changes in the ranking of motor and feeding functions in children [29]. Based on the WHO customised criteria, overnutrition is defined as Z-score > +2 standard deviations (SD); normal as Z-score = +2 SD to z = −2 SD; moderate malnutrition as Z-score < −2 SD to z = −3 SD; and severe malnutrition as Z-score < −3 SD [30]. The high sensitivity and convenience of the mean UAC and its large age group coverage make it a better screening indicator for malnutrition than the others [31].

Conclusion

Although malnutrition in children with CP is a prevalent problem affected by numerous factors, there is no optimal screening and assessment tool for assessing their nutritional status. We have summarised the existing screening and assessment tools to provide a reference for the future development of a nutritional assessment method for CP in China to reduce the incidence of malnutrition in children with CP and improve their quality of life.

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