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Review Article

Cerebral Palsy and Nutrition: Optimizing Growth and Development

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Received: July 05, 2023; **Published:** July 28, 2023

Abstract

Cerebral palsy (CP), is not a single disease but its the co-existance of more than one permenant disorders with no progression in neonatal brain resulted from certain neurological damages and its commonly seen in children. Neurological damages in brain may result in motor dysfunction and impaired posture as well as limited physical activity in affected children. Oral motor dysfunction and limited physical activity can diminish the total amount of food intake and oral motor dysfunction itself is the major factor associated with malnutrition which is the reason for poor growth in children with CP. According to the disease specific growth charts, children with CP have poor growth compared with their typically developing peers and there are multiple reasons behind this. There are different nutrition-dependent and nutrition-independent factors that responsible from growth retardation in children with CP, however these factors may affect each other throughgh different pathways. For example, endocrine problems such as damages in hypothalamacortical linkages and changed homeostasis of hunger-satiety signals as a nutrition-independent factor may lead to malnutrition in children with CP. Difficulties in chewing, swallowing and saliva control due to oral motor dysfunction can decrease the amount of food intake orally, therefore, to prevent further weight loss and malnutrition, enteral feeding may be considered for severely affected children. In adddtion, the presence of extended duration of mealtime and stressful environment during feeding for both children and caregiver may indicate the need for enteral feeding. Administiration of enteral feeding may vary depending on the tolerance of the children and the duration of feeding, however, gastrostomy tube feeding is often preffered over nasogastric tube due to its safe administiration and easy tolerance. Selecting the suitable enteral formulas in accordance to the toleration of the children is also important. It is necessary to plan an individual based nutrition program via taking the anamnesis and analysing the food records of the children. While determining the nutritional needs, disease specific growth charts and special equations developed for energy requirement calculations in children with CP can be a good "starting point".

Keywords: *Cerebral Palsy; Oral Motor Dysfunction; Growth Retardation; Malnutrition; Gastrostmoy Tube Feeding; Neurological Damage*

Abbreviations

BMR: Basal Metabolic Rate; CP: Cerebral Palsy; DLW: Doubly Labeled Water; DRI: Dietary Reference Intake; ESPGHAN: European Society of Paediatric Gastroenterology, Hepatology and Nutrition; GER: Gastroesophageal Reflux; GT: Gastrostomy Tube; USDA: United States Department of Agriculture

Introduction

Cerebral palsy (CP) occurs due to non-progressive neurological problems in neonatal brain. These disruptions are associated with unwanted results in development of motor function and posture. As a result of these problems mental capacity and physical activity ability of those children can be affected [1,2]. Cerebral palsy is mostly related with motor dysfunction. In addition to that disorders of growth and development as a consequence of nutritional impairments can be seen in children with CP [2]. Most of the children with CP have poorer nutritional status and visible features related to that nutritional status (e.g. weight and/or height below the expected levels) than their healthy peers [3]. Nutritional and non-nutritional factors may affect nutritional status of those children. Oral motor dysfunction which is affecting 90% of children with CP may cause malnutrition as a non-nutritional reason [4]. In addition to that motor dysfunctions may cause perceptional, congenital, sensational, communicative and behavioral alterations. Significant comorbidities, seizures (e.g. epileptic seizures) and musculoskeletal complications are also related with impairments in motor functions [5]. Various comorbidities such as epilepsy (15 - 90%), mental retardation (40 - 65%), difficulties in speech (50%), problems in controlling urination (30%), malnutrition and growth retardation (27%) difficulties in saliva control (10%), are commonly seen among children with CP [6]. Nutritional problems like malnutrition, gastroesophageal reflux (GER), constipation and insufficiency of certain macronutrients or vitamins and minerals may also be considered as comorbidities [5]. Endocrine system may also be affected in children with cerebral palsy. Growth hormone deficiencies, hypothalamic malfunctions are also having impact on dietary intake of those children [6,7]. Additionally, cognitive disruptions and extended utilization of anti-epileptic drugs are considered as nutrition independent factors associated with food intake [8]. For children with neurological disorders, nutritional wellbeing has notable effect over health and improved life quality; being underweight or overweight may require frequent health care utilization and decrease social and educational development of children [9]. This review aims to describe the possible nutritional management strategies and steps to be taken while setting those strategies by emphasizing its importance to support growth and development in children with CP.

Estimating the requirements of children with cerebral palsy

Clinical evaluation of children with CP should be carried out carefully as it's been done for their healthy peers and the important information such as amount of physical activity, existence of any comorbidities (gastrointestinal diseases, pulmonary disorders, contractures, scoliosis) and utilization of any medications, especially the ones for epilepsy that may alter nutrition, should be taken from the caregivers [8]. Afterwards information related with feeding history should be taken. Moreover, it's important to ask if there were any previous interventions affected child's growth and nutrition [3]. Considering the duration of mealtimes while evaluating neurologically impaired children in terms of feeding difficulties is necessary, for instance, if the feeding duration exceeds 3 hours daily with the presence of stress for both child and caregiver, getting consultation from expert feeding therapist for detailed assessment may be helpful [9,10]. Also, proper positioning and supporting child physically while feeding is significant for safety, such that some children may need extra head or body support in addition with individualized seat [11]. It is also necessary to know the feeding route of the child which might be tube or oral feeding [3].

Estimating energy intake

According to Scarpato., *et al*. 2017, current methods for estimating energy intake in children with CP are 3-day or 7-day estimated food diary as well as 3-day weighed food diary. However, each method has its own challenge for caregivers, for instance weighing and re-weighing the food prior to and after the meal in 3-day weighed food diary is difficult for them, also increased amounts of days make this record keeping process more challenging [12]. Study done by Walker and colleagues (2013), with the participation of 31 children who have CP with all different levels of motor function and 15 normally developed children, both groups were aged nearly four, proved the validation of modified three-day weighed food record by comparing the energy intake obtained from the records with the measured energy intake via DLW. In the study, caregivers were asked to report all the food and fluid intakes, including remained foods from meal and spilled foods during feeding, for two weekdays and a single weekend day and they were given kitchen scales and food record papers. To

conclude, if the caregivers are trained enough, the 3-day weighed food diary is the most promising method to estimate the energy intake of children with CP [8].

Estimating energy expenditure and energy requirements

Like anthropometric measurements, estimating the energy requirements in children with CP is also difficult to proceed since the equations for normally growing children, which were developed according to weight, height, age, and gender, are overestimating the energy expenditure for children who have CP [13]. Therefore, if the circumstances are suitable, children with CP must be measured via indirect calorimetry for estimating energy expenditure to avoid errors, as suggested by Scarpato and colleagues (2017) [8]. According to Andrew and Sullivan (2010) [7], equation used for indirect calorimetry includes the values of basal metabolic rate (BMR), muscle tone, physical activity level, and growth factor, in which muscle tone can be taken as 0.9 if it's low, 1.0 if it's normal and 1.1 if it's elevated. For activity levels 1.1 can be taken if the patient is bedfast, for wheelchair using patients 1.2 can be taken while 1.3 is appropriate for ambulatory patients. Lastly, for growth factor, 5 kcal/g of appropriate weight gain amount (to achieve normal weight or catch-up growth) can be added to the equation after multiplying the BMR, muscle tone and activity levels, however, this formula is only used as a reference and the impact of dietary management should be evaluated frequently and appropriate changes must be done for achieving desired growth. Since there are no established suggestions for assessing the energy requirements in children with CP, it is hard to define how energy requirements should be assessed in this group of children [14]. In addition, Dietary Reference Intake (DRI) values may be too much for children with CP due to their significant growth failure and low physical activity [15]. Also, presence of various types of neurologic conditions may create difference in energy requirements, thus, nutritional needs for children who have neurological disorders are too broad for general suggestions and estimations for energy requirements should be done for individual base [16]. For example, neurologically impaired patients need more energy to walk, however, patients with wheelchair need the 60 - 70% of the energy that normally developed children [17,18]. On the other hand, energy needs might increase with the higher levels of physical activity and estimations of energy requirements should be done based on this [11]. According to Walker and colleagues (2012), best way to determine the energy needs is to check the fat-free mass and ambulatory conditions. Furthermore, European Society of Paediatric Gastroenterology, Hepatology and Nutrition ESPGHAN recommendation for estimating energy requirements in children with CP is tracking the body weight and fat mass routinely [15]. To conclude, tracking patient regularly in terms of the nutritional status and the amount of weight gain is necessary to prevent overfeeding as well as underfeeding [11].

Nutritional intervention in cerebral palsy

Children with CP generally have altered growth patterns (poor growth) when they compared with the normally developing population and insufficient dietary intake as well as impaired nutrition was strongly linked with changed growth pattern [2,19]. Therefore, it's important to establish a well-planned nutritional intervention program for children with CP to improve the growth and development. Main aims of nutritional support should be; (a) achieving the weight that is plotted above 20^{th} percentile, which is out of concern area, on weight for age charts for children with CP, (b) aiming for children to be in 10^{th} to 25^{th} percentile for age on triceps skinfold measurements, (c) tracing the weight through 2 to 4 weeks intervalley, (d) meeting the age-matched calcium and vitamin D needs, (e) providing sufficient protein and micronutrients, which is nearly same with their healthy peers (f) providing sufficient energy, which must be calculated individually, however in the beginning for oral nutrition, energy intake may be 10% higher than currently taken energy [3]. Proper nutritional intervention must consider the age of patient as well as the clinical state, functionality of gastrointestinal system, safety and applicability of the oral intake, dietary pattern, and expenses [20]. At first, the aim should be improving oral feeding by appropriate positioning and physically supporting the children while feeding [18]. However, oral nutrition shouldn't be suggested if it is not compensating the nutritional needs of the child, if the process is stressful and not safe or mealtimes are exceeding 3 hours daily; in this case enteral tube feeding can be advised [16]. Even though there are no constant recommendations of nutrient intake of children with CP, adequate macro and micronutrients should be provided to children to support growth and development. Estimations of energy and protein needs of the children is

just a start point, routine assessment and follow-up is necessary for setting the exact nutritional goals, reaching the targeted aims of the nutritional intervention, and managing the complications of over or undernutrition [18].

Oral nutrition

According to the Scarpato and colleagues (2017) [8], oral nutrition can be continued in the absence of oral motor dysfunction and aspiration risk, as well as if the children have sufficient growth and development, and if the feeding durations are not exceeding tolerable limits [4]; also, establishing an oral nutrition rehabilitation program by cooperating with speech therapist and targeting to improve dietary intake as well as digestive functions of the children is necessary. Correcting the positioning of the patient and utilization of suitable seats and utensils while feeding is included in the rehabilitation program. Furthermore, changing the textures of foods and fluids according to the child's toleration can improve oral-sensimotor abilities and contribute to safe and efficient mealtime [21]. Although the oral feeding administrations improve the oral motor abilities, they may not be adequate for desired weight gain [14].

Enteral nutrition

Some of the children who have CP can tolerate total oral feeding, however, for most of them oral intake solely is not sufficient, safe, and stress-free due to dysphagia, prolonged mealtimes, and inadequate consumption, therefore different feeding options might be considered for those children [11]. According to ESPGHAN, intervention of enteral nutrition is advised if; (1) the oral consumption is not compensating the 60 - 80% of patient's needs, (2) the duration of mealtimes are more than 4 to 6 hours daily, (3) there is insufficiency in terms of gaining weight or in growth, (4) height velocity is decreased, (5) the triceps SFT is constantly below the 5^{th} percentile for age [20]. The route of enteral feeding changes according to patient's clinical condition and to the planned time of continuance of the regimen; although the nasogastric tube feeding has lesser extent of invasiveness, it may be removed by patient easily and may cause nasal congestion, sinusitis, and middle ear infection [8]. Therefore, gastrostomy tube (GT) feeding can be suggested for long duration of enteral feeding since GT is not removed easily and much more tolerated by the patients [14].

Generally, children who needs GT feeding have high levels of motor dysfunction, therefore they have decreased energy requirements when they compared with the children that are not affected [3]. Several studies were suggesting that, after the GT administration, energy needs of children with CP a may be 50 - 70% of their normally developing age matched peers [22,23]. Gastrostomy tube fed children might be exposed to overfeeding, therefore, beginning with the low-calorie amount and increasing it gradually (5 - 10% increments of the total intake), based on weight gain velocity and frequently checked anthropometric measurements, would be beneficial; additionally, doing the weight measurements during first two week of the GT administration is important for setting nutritional requirements and afterwards monthly measurements (after accomplishing the targeted goals, follow ups can be done for every 6 to 12 months) can be done for follow up [3,7].

As feeding regimen, continuous feeding is generally suggested for children with low toleration of bolus feeding, also its suitable for post-pyloric feeding in terms of preventing diarrhea and dumping syndrome [14,20]. On the other hand, if there is no GER or delayed gastric emptying, bolus feeding can be considered due to its consistency with hormonal and enzymatic processes [8]. Combining the nocturnal continuous feeding with the bolus feedings throughout the day might be necessary for adequate nutrient intake in children with CP [18].

Diet composition

Diet composition affects overall health status of individuals with cerebral palsy. A study was conducted by Brown and colleagues showed that adults with cerebral palsy were unable to meet the US Department of Agriculture (USDA) dietary quality recommendations. Another study by Penagini and colleagues (2015) [9] reported that, there aren't any recommendations which were depending on evidence in terms of nutrient intake and whether if increasing the protein and micronutrient (except vitamin D) amounts of neurologically

impaired children, however, the diet must include various foods for providing adequate macronutrients, vitamin, minerals, and fiber, also enough fluids to prevent dehydration [11]. Daily Recommended Intakes (DRI) of children with normal growth can be used in the absence of undernutrition, however if there is sign of undernutrition protein intake must be 2 g/kg/day and calorie amount should be increased by 15% to 20% for achieving catch up growth [9]. Regarding to vitamin D, children with CP are prone to have vitamin D deficiency due to multiple reasons such as low exposure to sunlight because of the non-ambulatory conditions, insufficient intake caused by feeding problems and prolonged utilization of anti-epileptic medications; if not treated, vitamin D deficiency may lead to osteopenia and fractures. In a study which has been conducted with 119 children with cerebral palsy, 42.9% of the participants had low vitmain D levels [26,27]. There is no consensus on exact dose of vitamin D supplementation which is appropriate for children with CP, however, as the experts of bone health suggest, 800 - 1000 UI of vitamin D, which is higher than the usual recommendations, is safe and must be taken into consideration for this group of children [28,29]. According to Rebelo and colleagues (2022) [5], two studies searched for the impact of vitamin D supplementation on the plasma levels of 25-hydroxyvitamin D in totally 63 children aged between 6 - 18; in first study, a single oral dose of 100,000 UI was given to the participants in comparison with placebo and for the second study, again a dose of 100,000 UI was given 5 days per week orally for 10 weeks in comparison with observational group. Both researches indicated that children who got the supplementation had improved 25-hydroxyvitamin D levels [30,31].

There are various enteral formulas that available commercially such as polymeric, semi-elemental and elemental formulas, which were suitable for different ages and altering nutritional needs according to these ages [18]. Many of the enteral formulas are developed for providing total nutrition as an only source of nutrition by compensating all the necessary nutritional needs [20]. At first, general recommendation is to prefer polymeric formulas with the standard energy density (1.0 kcal/ml) that is appropriate for the child's age, however, in the case of high energy requirements with low tolerance of high volumes, increased energy dense formulas (1.5 kcal/ml) can be preferred [18]. On the other hand, if the child has low energy requirements due to rapid weight gain, formulas with the decreased energy density (0.75 kcal/ml) can be provided [23]. In a pilot study of Savage and colleagues (2012) [24], which was searching for whether if the whey-based formulas are decreasing the GER and speeding up the gastric emptying compared with the casein-based enteral formulas; 13 children was fed by casein-based formula for a week, and they were also provided whey-based formula (50% whey whole protein or 100% whey partially hydrolyzed protein) for another week. According to this study, children with severe CP, who were fed by gastrostomy, found to have rapid gastric emptying for the ones who were fed with whey-based formula when they compared to children who got casein-based formula. However, this was not associated with any alterations in GER occurrence, thus no correlation was found between GER and enteral formula type (whey or casein based).

Another aspect to consider for diet composition of individuals with cerebral palsy is the possible beneficial effects of supplements. According to a randomized controlled clinical trial conducted by Leal-Martínez and colleagues (2020), supplementation of diet composition with nutrients like zinc, folic acid, probiotics, omega 3 fatty acids, cholecalciferol, arginine, glutamine and poly unsaturated fatty acids improved the standing and walking parameters significantly [32]. It is known that in the case of dysbiosis, the prognosis of neurodegenerative diseases such as Alzheimer's, Parkinson's and MS may worsen as a result of the bidirectional interaction between the gut-brain axis. These adverse effects are mostly due to dysbiosis in the gut. The increase in permeability is associated with an increase in circulating toxic metabolites and the passage of these toxic substances across the blood-brain barrier. It is stated that probiotic supplementation is a promising approach to restore intestinal balance and reduce the symptoms of some neurodegenerative diseases [33,34]. Another study found that supplementation with probiotics and prebiotics has improved functional constipation in children with cerebral palsy [35].

Conclusion

Cerebral palsy is a common disability seen among children, which occurs due to non-progressive, persistent neurological disruptions in developing brain. Children with CP have different growth patterns and diminished nutrient intake when they compared with their

healthy peers. Several studies indicated that children with CP have malnutrition due to multiple reasons such as feeding difficulties, endocrine factors, neurological impairments. Lack of growth hormone secretion was common in children with CP. Also, oral motor dysfunction, which is affecting 90% of the children with CP was found to have an impact on malnutrition. Therefore, it's significant to detect feeding or swallowing problems for preventing malnutrition in this group of children. Planning an individual nutritional intervention is increasing the quality of life and supporting growth and development in children with CP. Assessment of body composition and anthropometric measurements as well as evaluating feeding and clinical history are necessary steps to take while nutritional intervention, also, interpreting these data through CP specific growth charts is a significant starting point for nutrition plan. As for the first approach for nutritional intervention, oral nutrition of the children should be enhanced unless if there is swallowing problems, aspiration risk and/or insufficient nutrient intake. Otherwise, enteral nutrition may be considered to prevent malnutrition in children with CP. It's significant to provide sufficient macro and micronutrients to the children based on their individual needs for achieving the "catch up growth" as much as possible to their healthy peers.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Volume 18 Issue 7 July 2023