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Pre-operative nutrition assessments do not improve outcomes in cerebral palsy patients undergoing varus derotational osteotomy

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Abstract

Pre-operative nutritional assessments have been used as a "cornerstone" to help optimize nutritional status and weight in children with cerebral palsy (CP) to lower the risk of postoperative complications. However, the potential value of nutritional assessments on surgical outcomes in patients with CP undergoing major orthopedic surgery remains unproven.

Do pre-operative nutritional assessments reduce complication rates of varus derotational osteotomy surgery in children with CP? Are complication rates higher in patients with a gastrostomy tube (G-tube) and can they be decreased by pre-operative nutritional assessment?

One-hundred fifty-five patients with CP who underwent varus derotational osteotomy from January 1, 2012 through December 31, 2017 at a tertiary pediatric hospital with minimum 6 months follow-up were retrospectively identified. One-hundred-ten (71%) were categorized as "non-ambulatory" (Gross Motor Function Classification System [GMFCS] IV–V), and 45 (29%) as "ambulatory" (GMFCS I–III). Variables assessed included age, GMFCS level, G-tube, body mass index (BMI) percentile, complications, and if patients underwent pre-operative nutritional assessment.

One-hundred-eleven patients (71.6%) underwent pre-operative nutritional assessment. Sixty-two of 155 patients (40.0%) had G-tubes. In non-ambulatory patients with G-tubes, BMI percentile changes were not significantly different between patients with a pre-operative nutritional assessment compared to those without at 1 ($P = .58$), 3 ($P = .61$), 6 ($P = .28$), and 12 months ($P = .21$) postoperatively. In non-ambulatory patients who underwent pre-operative nutritional assessment, BMI percentile changes were not significantly different between those with and without G-tubes at 1 ($P = .61$), 3 ($P = .71$), 6 ($P = .19$), and 12 months ($P = .10$). Pulmonary complication rates were significantly higher in non-ambulatory patients with G-tubes than in non-ambulatory patients without G-tubes (20% vs 4%, $P = .03$). Pre-operative nutritional assessments did not influence postoperative complication rates for non-ambulatory patients with or without a G-tube ($P = .12$ and $P = .16$, respectively). No differences were found in postoperative complications between ambulatory patients with and without G-tubes ($P = .45$) or between ambulatory patients with or without nutritional assessments ($P = .99$).

Nutritional assessments, which may improve long term patient nutrition, should not delay hip surgery in patients with CP and progressive lower extremity deformity. Patients and their families are unlikely to derive any short-term nutritional improvement using routine pre-operative evaluation and surgical outcomes are unlikely to be improved.

Level of Evidence: III, retrospective comparative.

Abbreviations: BMI = body mass index, CP = cerebral palsy, GMFCS = Gross Motor Function Classification System, G-tube = gastrostomy tube, VDRO = varus derotational osteotomy.

Keywords: cerebral palsy, complications, femoral osteotomy, nutrition, varus derotational osteotomy

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This study has been carried out with approval from the Institutional Review Board at Children's Hospital Los Angeles.

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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1. Introduction

Cerebral palsy (CP) results from disturbances in the fetal or infant brain and is the most prevalent motor disorder in children. It is frequently associated with cognitive, behavioral, perceptive, seizure, and/or gastrointestinal manifestations.[1,2] The inability to chew and swallow, dysphagia, aspiration, and inadequate nutritional intake subsequently lead to 1 in 3 children requiring tube feeding, and can be compounded by constipation, gastroesophageal reflux, and vomiting.[1,3–7] Previous researchers have reported that 58% of patients with CP have feeding problems, and 23% have severe feeding dysfunction.[8] Kilpinen-Loisa et al[9] found that 57% of neurologically impaired children with severe motor disability received <80% of their recommended energy intake. Feeding neurologically impaired children impacts their caregivers, who often spend long hours feeding these children, as well as parents, who report the process to be stressful and unenjoyable.[10] These factors contribute to the large portion of children with CP having malnutrition and decreased growth.

Lower bodyweight and worse nutritional status in patients with CP have been reported to be risk factors for postoperative medical and surgical complications.[8,11,12] Patients with CP undergoing scoliosis surgery who were pre-operatively malnourished (albumin <3.5 g/L) were shown to have significantly longer hospitalizations and greater rates of postoperative infection (pneumonia, urinary tract infection, and wound infection) compared to nourished patients.[12] Additionally, a low body mass index (BMI) (<5th percentile WHO growth chart) was a risk factor for overall complications and medical complications in patients undergoing spine procedures.[13]

As a result, pre-operative assessments are often used to evaluate nutritional needs in patients with CP to potentially help with weight gain and to theoretically lower the risk of postoperative complications. Although a pre-operative nutritional assessment is considered a "cornerstone" to improve nutritional status and outcomes in children with CP, prior research suggests limited benefit of pre-operative nutritional assessments and nutritional rehabilitation on weight gain, particularly in patients with CP and concomitant feeding difficulty.[14] Additionally, these assessments can be costly due to the comprehensive evaluation and use of various resources.[15] At our institution, surgeons balance the potential risks and benefits of allowing progressive hip displacement – and the possible need for a more extensive and complicated surgery – with those of potentially improving nutritional status while surgery is delayed. Further, there are costs associated with such nutritional evaluations, including professional fees, facility fees, costs for laboratory tests, travel costs, and opportunity costs of lost work for the patient's parents.

We are not aware of any literature regarding the relationship and timeline of pre-operative nutritional assessments at improving nutritional status and outcomes in patients with CP undergoing major orthopedic surgery. The objective of this study is to assess the effect of pre-operative nutritional assessments on our patients with CP undergoing varus derotational osteotomy (VDRO) hip surgery.

2. Methods

After obtaining Institutional Review Board approval, a retrospective review was performed to identify patients with CP who underwent unilateral or bilateral VDRO between January 1, 2012 and December 31, 2017, had pre-operative height and weight measurements, and had a minimum 6-month follow-up. Variables identified included: age, Gross Motor Function Classification System (GMFCS) level,[16] length of hospital stay (days), height, weight, BMI, presence of a gastrostomy tube (G-tube), complications (including, but not limited to, pressure sores, urinary infection, pulmonary complications, wound complications, non-union, delayed union, and malunion), and whether the patient underwent a pre-operative nutritional assessment.

Routine anthropomorphic measurements of non-ambulatory patients with CP at our institution's pediatric, endocrine, orthopedic, and neurology clinics, are obtained through medical assistants who are trained to measure weight on a scale; if a child is weighed in a wheelchair, the child is weighed and the child's weight calculated by subtraction. For most children, height is measured with patient in recumbent position from head to heel with tape measure, as a second assistant straightens the extremities as much as possible in the presence of contractures. For children with severe contractures, limb segment measures are often substituted.

To account for the inaccuracies of anthropomorphic measurements in CP population, we also used CP specific growth charts to determine weight and BMI patient percentiles. Albumin and total protein could not be assessed as they were not routinely collected for the majority of our patients.

A nutritional assessment consisted of review of current and past anthropomorphic measurements documented in the chart, patient's current diet, and diet recommendations by the hospital nutritionist. A pre-operative nutritional assessment was defined as a patient being seen by a nutritionist anytime at least 2 weeks prior to surgery. The patients were categorized as "ambulatory" (GMFCS I–III) or "non-ambulatory" (GMFCS IV & V). Patients who had a nutritional assessment prior to surgery were compared to those who did not.

Statistical analysis was performed using Stata12 (College Station, TX: StataCorp LP) and Microsoft Excel (2010). *T* tests were used to identify differences between linear variables (BMI percentiles, length of stay). Chi-squared tests were used for univariate analysis to identify differences between categorical variables (GMFCS, G-tube, postoperative complication, non-ambulatory vs ambulatory, pre-operative nutritional assessment). Multiple regression was used for multivariate analysis of BMI percentiles, GMFCS groups (GMFCS I–III [ambulatory] vs GMFCS IV–V [non-ambulatory]), and G-tube placement, and their effect on postoperative complications, and hospital length of stay, in the setting of whether pre-operative nutritional assessments were performed. Significance was set at $P < .05$.

3. Results

3.1. Patient demographics

A total of 155 patients met the inclusion criteria, of which one (0.6%) of the patients were GMFCS I, 20 (12.9%) GMFCS II, 24 (15.5%) GMFCS III, 39 (25.2%) GMFCS IV, and 71 (45.8%) GMFCS V. Forty-five (29.0%) patients were classified as ambulatory (GMFCS I–III), and 110 patients (71.0%) as non-ambulatory (GMFCS IV–V).

One-hundred-eleven of the total 155 patients (71.6%) had a pre-operative nutritional assessment. Sixty-two of the 155 patients (40.0%) had G-tubes. When comparing the cohort who underwent a pre-operative nutritional assessment to those

Table 1

Demographics of patients with and without nutrition assessments. Body mass index (BMI) gastrostomy tube (G-tube).

	Nutrition assessment (n = 111)	No nutrition assessment (n = 44)	*P* value
BMI percentile	42.9 ± 26.7	50.5 ± 27.0	.12
Age	8.1 ± 3.7	8.2 ± 3.6	.84
G-tube	52 (47%)	10 (23%)	.01

Table 2

Gross Motor Function Classification System (GMFCS) distribution nutrition assessment vs no nutrition assessment.

	GMFCS I	GMFCS II	GMFCS III	GMFCS IV	GMFCS V	*P* value
Assessment	0	11	15	27	58	.04
No assessment	1	9	9	12	13	

who did not, the patients had similar BMI percentiles and age at surgery, while presence of G-tubes was significantly different between the 2 groups (Table 1). GMFCS level distribution was also significantly different between patients who underwent nutritional assessments and those who did not (Table 2).

3.2. Body mass index

Patients who underwent pre-operative nutritional assessment did not have significantly different changes in BMI percentile at 1 ($P = .58$), 3 ($P = .99$), 6 ($P = .47$), and 12 months ($P = .31$) postoperatively compared to those who did not (Table 3). Of the 111 patients who underwent pre-operative nutritional assessments, 75 (68%) had only the initial nutritional assessment, and the remaining 36 (32%) had at least 6 months follow-up. BMI percentile change was not significantly different between patients with only an initial assessment compared to those with follow-up at 1 ($P = .97$), 3 ($P = .11$), 6 ($P = .86$), and 12 ($P = .91$) months postoperatively. BMI percentile change was not significantly different between non-ambulatory patients with G-tubes who underwent a nutritional assessment compared to those who did not at 1 ($P = .58$), 3 ($P = .61$), 6 months ($P = .28$), and 12 months ($P = .21$) postoperatively. For non-ambulatory patients who underwent pre-operative nutritional assessments, postoperative change in BMI percentile was not significantly different between those with G-tubes compared to those without G-tubes at 1 ($P = .61$), 3 ($P = .71$), 6 ($P = .19$), and 12 ($P = .10$) months postoperatively.

Table 3

Postoperative body mass index (BMI) percentile change from pre-operative BMI for patients with nutrition assessments vs those without.

	One month	Three months	Six months	Twelve months
ΔBMI assessment	−2.1 ± 33.7	−3.5 ± 37.5	−1.5 ± 31.9	−1.4 ± 40.3
ΔBMI no assessment	−9.3 ± 30.7	−3.6 ± 27.5	−12.4 ± 45.3	−19.0 ± 42.9
P value	.58	.99	.47	.31

Table 4

Overall complication rate.

	Pressure sore	Pulmonary complication	Infection	Wound complication	Malunion
Number of patients (%)	27 (17.4%)	15 (9.7%)	6 (3.9%)	4 (2.6%)	2 (1.3%)

3.3. Complications

In the 155 patients, complications included 27 (17.4%) with pressure sores, 15 (9.7%) with pulmonary complications, 6 (3.9%) with urinary infection, 4 (2.6%) patients with wound complications, and 2 (1.3%) with malunions (see Table 4). Non-ambulatory patients had significantly greater overall rates of complications compared to ambulatory patients (34% vs 16%, $P = .03$). Patients who underwent nutritional assessment had a higher overall complication rate compared to those who did not (33% vs 16%, $P = .03$). Non-ambulatory patients who underwent nutritional assessment had a statistically significantly greater complication rate compared to those who did not (39% vs 13%, $P = .01$). Among ambulatory patients, the complication rate was the same between those with a nutritional assessment and those without (15% vs 15%, $P = .99$).

3.4. G-tubes

Feeding via a G-tube was independently predictive of overall complications (Odds Ratio: 3.69, Confidence Interval: [1.78–7.68], $P < .001$). In non-ambulatory patients, those who had G-tubes had significantly higher rates of pulmonary complications (20% vs 4%, $P = .03$). Postoperative infection rate was not significantly different between non-ambulatory patients with G-tubes compared to non-ambulatory patients without them (7% vs 4%, $P = .54$). For non-ambulatory patients with G-tubes, complication rates were similar whether or not they underwent pre-operative nutritional assessments ($P = .12$). Likewise, there was no significant difference in complication rates for non-ambulatory patients without G-tubes whether or not they underwent pre-operative nutritional assessments ($P = .16$). No differences were found in postoperative complication rate between ambulatory patients with and without G-tubes ($P = .45$).

3.5. Hospital length of stay

Average hospital stay was 2.9 days (range: 1–37 days). Non-ambulatory patients had a significantly longer length of stay compared to ambulatory patients (3.3 vs 2.1 days, $P < .05$). Hospital length of stay was longer in those patients who had a nutritional assessment prior to surgery (3.6 vs 1.4 days, $P = .0005$). Presence of a G-tube did not result in a statistically significant difference in length of stay among ambulatory (2.1 vs 2.0 days, $P = .89$) or non-ambulatory patients (3.9 vs 2.5 days, $P = .07$), though there was a trend toward longer stays in the non-ambulatory G-tube group.

4. Discussion

This study is the first to assess the impact of pre-operative nutritional assessment on the rate of complications in patients with CP undergoing VDRO surgery. In our study, patients with

CP undergoing VDRO who had a pre-operative nutritional assessment did not have significantly better outcomes, complications, or changes in weight, BMI, or growth percentile over time compared to those who did not.

Previous literature suggests that pre-operative nutritional assessments are helpful to improve health status in patients with CP.[15] Malnutrition has been identified as a factor contributing to increased postoperative complications due to weakened immunity, healing, and worsened gastroesophageal reflux.[12,17]

4.1. No changes seen with nutritional assessment

Despite the perceived importance of pre-operative assessments to improve the nutritional status in CP patients, the current study found no differences in BMI percentile at 1, 3, 6, or 12 months postoperatively between patients who received nutritional assessments and those that did not. Nutrition follow up through 1 year did not significantly improve patient BMI percentile compared to those who only underwent an initial assessment. Although patients in the non-assessment group had a noticeably larger decrease in BMI percentile at 6 and 12 months compared to those receiving a nutritional assessment, the large standard deviation in each cohort rendered these findings non-significant (Table 3).

It is likely that many of the patients in the non-ambulatory group, especially with G-tubes had already had some nutritional assessment through their pediatrician, a gastroenterologist, or a nutritionist at another facility. At our institution, patients with G-tubes routinely are followed by nutritionists and gastroenterologists, who address their ongoing nutritional needs, which may be adjusted around times of increased metabolic needs, such as surgery. Consequently, an additional nutritional assessment pre-operatively may be of limited benefit.

4.2. Postoperative complications

It is somewhat surprising that pre-operative nutritional assessment did not appear to decrease the risk of complications in this large series of patients undergoing VDRO. The lack of improvement observed with nutritional assessment may be due to concomitant patient and social factors such as caretaker compliance with nutrition recommendations, neurotropic effects, endocrine abnormalities, spasticity, or immobility, which all contribute to malnutrition and may be challenging to modify in this patient population.[18]

The higher rates of overall complication rate in non-ambulatory patients compared to ambulatory patients (34% vs 16%, $P = .03$) is similar to previous findings by Lee et al,[19] in patients with CP undergoing lower extremity or hip reconstructive surgery. However, Lee et al did not compare complication rates between non-ambulatory and ambulatory patients with G-tubes. We found that the rate of postoperative pulmonary complication was significantly higher in non-ambulatory patients with G-tubes compared to non-ambulatory patients without G-tubes (20% vs 4%, $P = .03$). This may be due to non-ambulatory patients with G-tubes being at greater initial risk for postoperative complication, related to the G-tube itself or their feedings.[19–21] Conversely it may be that the presence of a G-tube is simply a marker for more severe disease involvement that contributes to a higher complication rate.

Stasikelis et al[22] previously reported extremely high complication rates following reconstructive hip surgery in children with CP who have G-tubes. Despite limiting complications tallied to "death, fracture, or decubitus ulcer," they reported complications in their 69% of 16 patients with G-tubes, including 2 patients (12.5%) who died.[22] They did not note whether or not their patients underwent pre-operative nutrition assessments.

Interestingly, in the current study, the overall complication rate was higher in non-ambulatory patients with G-tubes who underwent nutritional assessments compared to those who did not ($P = .01$). Although we initially suspected this represented some selection bias, the BMI was similar between those who did and did not have assessments. Additionally, the rate of complication was not significantly different between ambulatory patients with G-tubes who underwent nutritional assessments compared to those that did not ($P = .45$). This suggests that nutritional assessments may not be effective in patients with CP with G-tubes, regardless of GMFCS level. This may be because those patients that have G-tubes have already been seen by the nutritionist previously and although their nutritional status may still not be ideal, the modifiable factors have likely already been addressed and the patient has plateaued.

4.3. Longer hospital stays

Patients undergoing pre-operative nutritional assessments also had a significantly longer length of stay (3.6 days vs 1.4 days, $P = .0005$), which was in part attributable to their needing to meet specific nutrition and feeding guidelines prior to hospital discharge. These prolonged hospital stays obviously increased the cost of the hospital stay. Lack of improvement in postoperative outcomes and long-term BMI percentile changes in patients receiving nutritional assessments, especially those with G-tubes, indicate that a pre-operative nutritional assessment may not be warranted, particularly in the presence of progressive musculoskeletal deformity.

In addition, pre-operative nutritional assessments themselves use various resources, resulting in extra costs for patients, their families and providers. These include professional fees, facility fees, laboratory testing fees, travel costs, and opportunity costs for parents' missing work. Further, a delay in surgery may result in progressive hip displacement, and the need for more extensive surgery, without evident benefit of such pre-operative assessments in this patient population. In light of the short-term burden these nutritional assessments can have on the patient, family, orthopedic surgeon, primary providers, and family, we should devote more time to understanding where nutrition fits into the timing of surgical optimization of children with CP.

4.4. Limitations and future directions

This study does have limitations, mostly owing to its retrospective nature; however, it is unique in that it is the first to observe the relationship timeline of a nutritional assessment to neuromuscular hip surgery (VDRO) in patients with CP.

The retrospective nature of this study limited the retrievable information to what was available in the electronic medical record, including albumin and/or total protein levels prior to surgery, so analyses based on these values were not possible.

4.5. Limitations – using height/BMI in CP research

Additionally, height measurements used to calculate BMI may not be fully accurate in children who have significant

contractures.[23] Many of these children have missing height measurements throughout follow-up due to the inability to measure standing height.[24] In addition, patients who had stable postoperative weight may not have followed up for further weight checks, thus limiting the sample size. Consequently, in our study, BMI changes at each follow-up point were limited to patients who returned and had recorded heights and weights. Although a selection bias may exist, we do not believe it was a significant factor since BMIs were similar between those who did and did not receive a nutritional assessment (Table 1). To account for the inconsistencies of measuring height in this population, we also adjusted our data for this variable using CP-specific growth charts, "weight-based charts" and "BMI based charts" created in 2011.[11,23,25–27]

Currently all literature after 2011 comparing nutrition in patients with CP to orthopedic surgery outcomes uses BMI as the primary variable,[13,26] with the latest study to use albumin levels in 1993.[12] A handful of these papers are based off of large databases, such as the National Surgical Quality Improvement Program, in which BMI and height are not recorded using validated measurements.[13,23]

Despite its drawbacks, BMI has continued to be used in all CP orthopedic literature because it encompasses the multifactorial picture of malnutrition into a single value. In a study attempting to validate the new CP growth charts among a different cohort of patients from a different country, BMI was the most similar between cohorts compared to weight and height, despite the challenges behind measurements.[27]

There exist multiple verified measurement alternatives to BMI in patients with CP, such as skin fold thickness of triceps or subscapularis, knee height, upper arm length, arm cross-sectional area, and Bioelectric Impedance Analysis. However, the training and logistical challenges of recording these values routinely in the clinical setting limit their availability.[15,26]

4.6. Limitation – who gets a nutritional assessment?

Because of the retrospective design of our study, we could not develop a protocol to for which patients to get a nutritional assessment prior to surgery. However, the majority of patients (71.6%) did have a nutritional assessment at some point prior to surgery due to low pre-operative body weight. However, as many institutions started to move to routinely obtaining pre-operative nutritional assessments for all patients with CP scheduled to undergo VDRO, our institution did the same. The goals of our study were to observe what happened to our patients at different time points after a nutritional assessment, and then following surgery. Future prospective designs to randomize who gets a nutritional assessment may not be ethical.

4.7. Should malnutrition delay hip surgery?

Pre-operative nutritional assessments have been believed to be helpful to decrease the postoperative risk associated with malnutrition in patients with CP. Intuitively, optimizing nutrition prior to operative intervention would be expected to minimize complications (particularly wound complications, infections, and pressure sores). However, the current study found no benefit to delaying hip surgery in patients with CP with progressive deformity in order to improve nutrition. This nutrition plateau is likely due to a combination of factors from caretaker compliance to the severity of the disease. In fact, the goals of orthopedic surgery in patients with CP are largely for caretaker ease and satisfaction, which should improve patient nutrition as they are better cared for after surgery.[21] Recent work has shown a correlation between increased migration percentage of hips in children with CP and lower health related quality of life.[28]

Patients who had a pre-operative nutritional assessment did not have a significantly lower postoperative complication rate compared to those who did not. Additionally, long-term changes in BMI were not significantly different between patients receiving nutritional assessments and those who did not, in either patients with or without G-tubes. As a result, the pre-operative nutritional assessment, while potentially beneficial in long term (improving care of patient at home, developing good feeding habits, finding a diet regimen tolerated by patient), does not appear to have a short-term peri-operative benefit in these patients. In fact, delaying surgery may decrease quality of life in the short-term of the patients and families, and may ending up requiring a larger surgery to sufficiently address the child's neuromuscular hip displacement.

4.8. Conclusion

This is the first study observing the relationship between formal nutritional assessment and orthopedic surgical outcomes in children with CP, specifically VDRO hip surgery. Our data suggest that nutritional assessments, which may improve long term patient nutrition, should not delay hip surgery in patients with CP and progressive lower extremity deformity, as the patient and family are unlikely to derive any short term nutritional improvement using routine pre-operative evaluation, the surgery undertaken may be more extensive, and surgical outcomes are unlikely to be improved. Future longitudinal studies that analyze the effects of a pre-operative nutritional assessment using albumin, total protein, leptin, and specialized CP body fat measurements may further help define the changes in physical exam and labs values physicians should be looking for and the timing of patient benefit to be expected.[12]

Author contributions

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References

[1] Quitadamo P, Thapar N, Staiano A, Borrelli O. Gastrointestinal and nutritional problems in neurologically impaired children. Eur J Paediatr Neurol 2016;20:810–5.
[2] Venkateswaran S, Shevell MI. Comorbidities and clinical determinants of outcome in children with spastic quadriplegic cerebral palsy. Dev Med Child Neurol 2008;50:216–22.
[3] Figueroa MJ, Rojas C, Barja S. Morbimortality associated to nutritional status and feeding path in children with cerebral palsy. Rev Chil Pediatr 2017;88:478–86.
[4] Johnson A, Gambrah-Sampaney C, Khurana E, et al. Risk factors for malnutrition among children with cerebral palsy in Botswana. Pediatr Neurol 2017;70:50–5.
[5] Ravelli AM, Milla PJ. Vomiting and gastroesophageal motor activity in children with disorders of the central nervous system. J Pediatr Gastroenterol Nutr 1998;26:56–63.
[6] Reilly S, Skuse D, Poblete X. Prevalence of feeding problems and oral motor dysfunction in children with cerebral palsy: a community survey. J Pediatr 1996;129:877–82.
[7] Sondheimer JM, Morris BA. Gastroesophageal reflux among severely retarded children. J Pediatr 1979;94:710–4.
[8] Fung EB, Samson-Fang L, Stallings VA, et al. Feeding dysfunction is associated with poor growth and health status in children with cerebral palsy. J Am Diet Assoc 2002;102:361–73.
[9] Kilpinen-Loisa P, Pihko H, Vesander U, Paganus A, Ritanen U, Mäkitie O. Insufficient energy and nutrient intake in children with motor disability. Acta Paediatr 2009;98:1329–33.
[10] Sullivan PB, Lambert B, Rose M, Ford-Adams M, Johnson A, Griffiths P. Prevalence and severity of feeding and nutritional problems in children with neurological impairment: Oxford Feeding Study. Dev Med Child Neurol 2000;42:674–80.
[11] Brooks J, Day S, Shavelle R, Strauss D. Low weight, morbidity, and mortality in children with cerebral palsy: new clinical growth charts. Pediatrics 2011;128:e299–307.
[12] Jevsevar DS, Karlin LI. The relationship between preoperative nutritional status and complications after an operation for scoliosis in patients who have cerebral palsy. J Bone Joint Surg Am 1993;75:880–4.
[13] Minhas SV, Chow I, Otsuka NY. The effect of body mass index on postoperative morbidity after orthopaedic surgery in children with cerebral palsy. J Pediatr Orthop 2016;36:505–10.
[14] Asgarshirazi M, Farokhzadeh-Soltani M, Keihanidost Z, Shariat M. Evaluation of feeding disorders including gastro-esophageal reflux and oropharyngeal dysfunction in children with cerebral palsy. J Fam Reprod Health 2017;11:197–201.
[15] Scarpato E, Staiano A, Molteni M, Terrone G, Mazzocchi A, Agostoni C. Nutritional assessment and intervention in children with cerebral palsy: a practical approach. Int J Food Sci Nutr 2017;68:763–70.
[16] Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol 1997;39:214–23.
[17] Lewis D, Khoshoo V, Pencharz PB, Golladay ES. Impact of nutritional rehabilitation on gastroesophageal reflux in neurologically impaired children. J Pediatr Surg 1994;29:167–9. discussion 169-170.
[18] Tomoum HY, Badawy NB, Hassan NE, Alian KM. Anthropometry and body composition analysis in children with cerebral palsy. Clin Nutr Edinb Scotl 2010;29:477–81.
[19] Lee SY, Sohn H-M, Chung CY, et al. Perioperative complications of orthopedic surgery for lower extremity in patients with cerebral palsy. J Korean Med Sci 2015;30:489–94.
[20] Luhmann SJ, Furdock R. Preoperative variables associated with respiratory complications after pediatric neuromuscular spine deformity surgery. Spine Deform 2019;7:107–11.
[21] Blumetti FC, Wu JCN, Bau KV, et al. Orthopedic surgery and mobility goals for children with cerebral palsy GMFCS level IV: what are we setting out to achieve? J Child Orthop 2012;6:485–90.
[22] Stasikelis PJ, Lee DD, Sullivan CM. Complications of osteotomies in severe cerebral palsy. J Pediatr Orthop 1999;19:207–10.
[23] Day SM, Strauss DJ, Vachon PJ, Rosenbloom L, Shavelle RM, Wu YW. Growth patterns in a population of children and adolescents with cerebral palsy. Dev Med Child Neurol 2007;49:167–71.
[24] Kuperminc MN, Stevenson RD. Growth and nutrition disorders in children with cerebral palsy. Dev Disabil Res Rev 2008;14:137–46.
[25] Preedy VR. Handbook of Growth and Growth Monitoring in Health and Disease. 2011;Springer Science & Business Media,
[26] Baranek ES, Maier SP, Matsumoto H, et al. Gross motor function classification system specific growth charts-utility as a risk stratification tool for surgical site infection following spine surgery. J Pediatr Orthop 2019;39:e298–302.
[27] Wright CM, Reynolds L, Ingram E, Cole TJ, Brooks J. Validation of US cerebral palsy growth charts using a UK cohort. Dev Med Child Neurol 2017;59:933–8.
[28] Jung NH, Pereira B, Nehring I, et al. Does hip displacement influence health-related quality of life in children with cerebral palsy? Dev Neurorehabil 2014;17:420–5.