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Original article

Micronutrient intakes in enterally and orally fed children with severe cerebral palsy☆

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SUMMARY

Background & aims: This study aims to investigate micronutrient balance in children with Cerebral Palsy (CP), due to a paucity of this literature and their well documented issues with undernutrition.
Methods: Twenty-one children aged 4–12 years with marked CP fed orally (O, $n = 12$) or enterally (PEG, $n = 9$) were recruited, including age matched typically developing children (C, $n = 16$). Parents collected three consecutive days food replica of their child's actual intake and the contents directly analysed. Values were calculated as percentage (%) of Estimated Average Requirement (EAR) or Adequate Intake (AI) where applicable.
Results: Micronutrient intakes varied widely. Significant differences were found for Zinc: mean(±SD%) between PEG = 379(153) versus both O = 185(67) and C = 171(54) $p < 0.001$ and Iron: PEG = 311(93) versus O = 110(54) and C = 179(108), $p = 0.001$ and Copper: PEG = 162(±70); O = 44(±30); C = 78(±23) $p < 0.001$. Many O and C consumed insufficient iodine or calcium, including less than AI in potassium and manganese. Sodium intakes in 6/16 C were in excess of upper safety limits and 4/9 PEG consumed excessive Zinc.
Conclusions: Micronutrients have the potential to competitively inhibit one another in excess or deficiency through limiting their metabolism. In light of this, further investigations should assess the physiological impact of dietary imbalances, particularly in populations with limitations in their food consumption.

1. Introduction

Children with severe cerebral palsy commonly have feeding difficulties due to a variety of factors including dysphagia, gastro-esophageal reflux, problems with oral motor control and self-feeding ability.[1] These can often lead to malnutrition which is believed to impair growth in many such children.[2]

Percutaneous gastrostomy feeding (PEG) is thought to assist children to correct growth impairments due to malnutrition and should be prescribed to meet 100% of recommended dietary allowances (RDA's) for vitamins and minerals.[3] Defining appropriate energy requirements for patients with severe neurodevelopmental disabilities is particularly challenging.[4] Commonly utilised equations and formulae to predict resting energy expenditure typically overestimate this parameter in these children and hence the derived energy requirements are also inaccurate.[5] Previous studies in children with severe CP have also demonstrated issues in correlating energy intake and anthropometric z-scores[6] or the ratio of energy intake to expenditure and anthropometric z-scores, body fat percentages or circumferences.[7] As such it is likely that there is further underlying metabolic issues in these children which warrant further investigation.

Bioavailability of nutrients may be affected by the concentration of the nutrient and in which chemical form it exists, current nutritional status and health of the individual, as well as other dietary factors and nutrient–nutrient interactions.[8] The most notable trace element interactions being high levels of iron depressing copper and zinc absorption, increased zinc also decreasing copper absorption and raised copper intakes lowering zinc absorption.[9]

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Micronutrient imbalances lead to a myriad of consequences ranging from milder forms which are clinically much more difficult to recognise, to severe deficiency syndromes. These generally occur progressively beginning with the biochemical and metabolic consequences associated with subclinical deficiencies.[10]

Much of the current nutrition literature in children with CP investigates undernutrition energy intake and expenditure, with little information relating to micronutrition and nutritional balance. Food intake data available are also derived from a variety of food diary methods, which calculate values based on published food tables. Previous studies have utilised food intake diaries to estimate micronutrient provisions[7,11] for insufficient length to give an accurate assessment of genuine intakes[12] or 4-day weighed food records[13] which may suffer by the accuracy of comparison of food tables with the food consumed.[14] Energy intake from food records compared with measured resting energy expenditure, have also suggested a gross overestimation of food consumption via the use of food records in children with CP.[15]

The aim of this study was therefore to compare levels of protein, energy, minerals and trace elements found directly in actual food intakes in these children, to address these gaps and shortfalls in methodology within the literature. Comparisons were made between either orally or enterally fed children with severe CP, as well as typically developing children to serve as controls. This new information attempts to gain a wider view of their nutritional status, in order to attempt to elucidate potential mechanisms contributing to commonly found growth impairments in children with severe CP.

2. Materials and methods

Children with marked CP ($n = 20$) aged between 4.0 and 11.9 years, mean (±SD) = 7.3 (±2.0 years), were recruited from the Royal Children's Hospital, Brisbane, Australia. These children were classified as either Gross Motor Function Classification Scale (GMFCS) level IV ($n = 8$) or V ($n = 13$), which includes children who are non-ambulatory and both orally (O = 12) and PEG-fed (PEG = 9). A control group consisting of age matched, typically developing healthy children (C = 16) mean age (±SD) = 7.5 (±2.4 years), were recruited as part of a larger observational study. The study was approved by ethics committees of the Royal Children's Hospital (2007/117), The University of Queensland (2006000409) and Cerebral Palsy League of Queensland (2008/2009 1021). Informed consent was gained from parents and assent from the children where possible.

Exclusion criteria included coexistence of specific chronic diseases such as renal, cardiac or identified metabolic disorders, as well as gastric resection, which may otherwise confound results.

Parents collected duplicates of all foods consumed by their children over 3 consecutive days. This food composite was macerated and homogenised, then subsamples analysed for the direct quantity of minerals, trace elements, energy and protein. A sample of all fluids consumed were collected separately, along with their quantity, and calculated along with food quantities, to give an accurate representation of consumption values.

The trace element levels in composite food and liquid drink samples were analysed by inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7500a) after digestion with nitric acid using microwave digestion system (CEM MDS 2100). Details of ICP-MS analysis are described elsewhere.[16] For iodine analysis, the samples were digested in alkaline solution of tetramethylammonium hydroxide (TMAH) prior to ICP-MS analysis.[17]

After digestion of subsamples in nitric acid using microwave digestion system, the levels of minerals were analysed by inductively coupled plasma atomic emission spectrometry (ICP-AES, Varian, Vista AX), as previously described.[18] For protein analysis, the food samples were digested in sulphuric acid with added catalyst of copper sulphate. The samples were then analysed for nitrogen content using a Buchi Kjeldahl Digestor Unit (Buchi K438). The levels of nitrogen in the samples were used to calculate for protein levels by using a converting factor of 6.250.[19] All analyses were carried out with standard reference materials and laboratory in-house reference materials for quality control assurance.

Nutritional intakes of PEG-fed children were calculated using food panel information provided by the relevant product companies, along with the volumes consumed per day. All total values are reported as percentage of estimated average requirement (EAR) or as adequate intake (AI) for age and gender, as outlined by the National Health and Medical Council (NHMRC) nutrient reference values for Australia and New Zealand.[20]

Z-scores were calculated for values which are known to differ due to increasing age and gender, such as height, weight and BMI. These were calculated from the Centers for Disease Control (CDC 2000) growth data and a previously published data set,[21] respectively. Statistical analyses were conducted with comparisons between means obtained via ANOVA. P values were calculated via post hoc least significance for difference test. P values below 0.05 were considered statistically significant.

As no previous data exists in this area, a sample size of $n = 16$ was selected to detect a statistically significant difference if the means between the groups varied by 1 standard deviation. Where $n = 9$ a difference would be found at 1.8 standard deviations and $n = 12$ at 1.3 standard deviations.

3. Results

Participant characteristics and anthropometric data are presented in Table 1. Percentages of EAR or AI of energy and protein intakes, as well as trace element and mineral intakes are presented in Table 2 and Table 3 respectively.

In our cohort of orally fed children with CP, anthropometric data demonstrate significantly reduced z-scores = mean (±SD); weight = −1.92 (±1.59), height = −1.68 (±1.0) and BMI = −1.06 (±1.62) compared with controls and in agreement with previously published normative data sets. The PEG-fed group on the other hand only showed reductions in z-scores = mean (±SD); height = −1.75 (±0.90) and weight = −0.73 (±1.24), but not BMI = 0.52 (±1.01). This was due to lower weight z-scores in orally fed children which also reached statistical significance when compared to PEG-fed children.

Protein intakes were found to be significantly higher in the control group, compared to both the orally and PEG-fed children ($p = 0.005$). Despite this finding, all of the groups were consuming well over the current recommendations for protein intake per age and gender. Energy intake for the PEG group, as calculated via enteral feed labels and amount consumed, was found to be slightly reduced from relevant percentage of estimated average requirements = mean (±SD); = 90 (±35). Energy intakes via bomb calometry analysis, were significantly higher in controls = 172 (±63), compared to the other groups, $p = 0.006$.

Magnesium intakes were significantly reduced in the orally fed children with CP compared to the other groups and was also found to be below recommendations in 7/12 of these children. In comparison, only 2 children out of each of the PEG and control groups had insufficient magnesium intakes. As a group, orally fed children with CP also had inadequate intakes of calcium, copper, potassium, iodine and manganese. All of the children in our cohort had less than adequate intakes of potassium, while control children also consumed inadequate copper. As these assumptions are based on group average, it doesn't highlight high levels of inadequacy in