Relationships between Dietary Intake and Body Composition according to Gross Motor Functional Ability in Preschool-Aged Children with Cerebral Palsy

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Abstract

Background/Aims: We aimed to determine the relationships between energy intake, macronutrient intake and body composition in preschool-aged children with cerebral palsy (CP) according to gross motor functional ability in comparison with typically developing children (TDC).

Methods: Seventy-three children with CP (70% male) of all functional abilities and 16 TDC (63% male) aged 2.8 ± 0.9 years participated in this study. Dietary intake was measured via a validated 3-day weighed food record. Body composition was determined via isotope dilution techniques.

Results: There was a significant relationship between energy intake and fat-free mass index, which was stronger in TDC compared to children with CP. There were no significant correlations between other dietary intake and body composition variables, despite differences in body composition as ambulatory status declined. Non-ambulant, tube-fed children had significantly lower protein intakes compared to orally fed children. No other differences in macronutrient intake between children with CP and TDC were apparent.

Conclusions: Results suggest that relationships between dietary intake and body composition are not evident in this population, but develop over time. Physical activity levels may have a greater impact on body composition at this age. Longitudinal research is required to examine these factors.

Introduction

Growth in the majority of children with cerebral palsy (CP) remains atypical [1–3], despite continued research interest. Nutritional concerns are evident regardless of a child’s gross motor functional ability level, motor type or distribution [4–8], and have the potential to persist into adulthood [9]. Altered body composition (namely decreases in fat-free mass (FFM), and differing levels of body fat) [6, 10–16] and inadequate dietary intake [17–19] have been detailed in children with CP. These nutritional factors may help explain the aetiology of atypical growth and development in this population [5, 7, 8]; however, the links between them are not well established.
Previous literature has shown that nutritional rehabilitation can alter body composition in children with severe CP [15, 19]. Studies have focused on the effects of gastrostomy feeding, and have reported significant increases in various body composition parameters [10, 15, 20]. For example, in 21 non-ambulant children with severe CP aged between 4–18 years, the introduction of gastrostomy feeding was shown to significantly increase total body protein and body fat over a median time frame of 20.6 months [15]. Unfortunately, there was no ability to associate these outcomes to increases in specific nutrients as dietary intake was not measured. Sullivan et al. [19] investigated the effect of 12 months of gastrostomy tube feeding on the body compositions of 57 children aged between 5 months and 17 years, 95% of whom were not ambulatory. Findings of significant increases in subcutaneous fat deposition were associated with increased energy intake, which was predominately associated with increased fat intake. Body composition measures, however, were not via a gold standard.

A recent study showed that targeted nutritional rehabilitation has the potential to alter body composition favourably [20]. Excessive deposition of body fat was avoided by using a low-energy, micronutrient-complete enteral feed. Follow-up data for 5 children indicated significantly increased linear growth and weight gain with no disproportionate change in body fat storage [20]. Whether these outcomes were due to changes in dietary fat intake, protein intake or overall energy intake remains unclear and requires further investigation. Published literature currently only concerns those non-ambulant children with severe CP.

Knowledge of the relationships between dietary intake and body composition in preschool-aged children with CP of a range of functional abilities is extremely important to guide further studies regarding nutritional rehabilitation in children with CP of all ages in addition to clinical practice. The aim of this study was to determine the relationships between energy intake, macronutrient intake and body composition via a gold standard measure in preschool-aged children with CP according to gross motor functional ability in comparison to typically developing children (TDC).

**Subjects and Methods**

**Participants**

All children with CP were recruited from two prospective, longitudinal, representative cohort studies, which were funded by the National Health and Medical Research Council (NHMRC) of Australia: the Queensland CP Child Study of Motor Function and Brain Development (NHMRC 465128, n = 240) and the Queensland CP Child Study: Growth, Nutrition and Physical Activity (NHMRC 569605, n = 240), being conducted by the Children's Nutrition Research Centre (CNRC) and the Queensland Cerebral Palsy Research and Rehabilitation Centre. Eligible children were required to have a confirmed diagnosis of CP by a neurologist or developmental paediatrician [21], be aged between 1.4 and 5.1 years at the time of assessment, and residing in Queensland, Australia. Children with a progressive or neurodegenerative lesion, or a genetic abnormality known to impact on growth or body composition were excluded. Recruitment for TDC was via advertisements through the University of Queensland, CNRC website, and word of mouth. Typically developing siblings of the children with CP were also invited to participate. Children were eligible if they were living in Queensland, Australia, were in the same age range, and had no condition or were taking no medications that altered body composition. This was confirmed on screening with parents at study entry. Children with CP or TDC who were under- or overweight were not excluded from this study in order to obtain a representative sample. Parents or legal guardians gave written, informed consent on behalf of the participants. Appointments were conducted at the closest tertiary centre or at one of nine outreach locations for all children. The same study team collected data at all geographic locations. Corrected age was calculated for children under 2 years of age who were born at less than 37 weeks gestation. Chronological age was used for all other children.

**Anthropometry**

All measurements were taken by one of three trained dietitians. Body weight was measured to the nearest 100 g using portable electronic scales (Homemaker Ltd, Australia) or chair scales (Seca Ltd, Germany). A portable length measuring board (Shorr Productions, USA) was used to measure height or length (for children under 2 years of age or those unable to stand correctly) to the last completed millimetre. In children where an accurate measure of height or length was not possible, knee height was measured with an anthropometer (Holtain Ltd, UK) to the last completed millimetre. Knee height was then used to predict height using published equations developed previously from a population of children with CP [7].

**Dietary Intake**

A 3-day, weighed food record was completed for each child by parents or carers, detailing all food and fluids consumed over 2 weekdays and 1 weekend day [22]. Families were provided with the necessary equipment, including kitchen scales accurate to 0.1 g and a paper-based 3-day food record [23]. The record was adapted by a dietitian specifically for the study, and parents were asked to record foods and fluids offered as well as leftovers and spills to obtain specific amounts actually consumed by their child. Parents were encouraged to include the brand names of foods and fluids, any recipes used, and provide details on cooking method. One research dietitian coded and analysed all food records using the Foodworks™ dietary analysis software (2009; Xyris Software, Australia). Before analysis, inconsistencies in records were checked extensively with parents via telephone. Mean energy intake calculations (kJ/day) for each child were weighted according to the days recorded. The 2 weekdays had a significant-
ly greater impact upon the mean energy intake value when compared to the 1 weekend day, as they represent 5/7 of a weekly energy intake value. This modified 3-day weighed food record has been shown to accurately measure energy intake in a subset of this cohort of children. In a sample of 31 children aged 3.7 ± 0.5 years of all gross motor functional abilities and motor types, the bias in energy intake measured via the record as a percentage of total energy expenditure measured by the doubly labelled water method was lower than 15% [62]. This is less than published data detailing typical within-subject variability in day-to-day energy intake [24]. Energy intake data were expressed as kilojoules per kilogram FFM per day. The power to which FFM was raised to adequately adjust for body composition and body weight was determined by the log-log regression of energy intake and FFM [25]. This was done separately for the children with CP and the TDC due to known differences in the relationship between total energy expenditure and FFM [16].

Body Composition
Isotope dilution procedures were used to non-invasively measure body composition. The deuterium dilution technique [26] was used for the majority of children (59 children with CP) and oxygen-18 was used for 14 children with CP and all 16 TDC [27]. This was due to a small subset of the children being involved in a concurrent study investigating total energy expenditure via the doubly labelled water method. The dilution space for oxygen-18 was used to determine body composition for these children instead of deuterium due to greater accuracy [28, 29]. Children were given a dose of deuterium or oxygen-18 in the form of water, either orally or via a feeding tube. Prior to dosing, a single urine sample was collected from each child to determine natural baseline enrichments of the isotopes in the body. For the deuterium dilution technique, a second urine sample was collected approximately 5 h after dosing [26]. If the child was dosed with oxygen-18, daily samples were collected for the 10 days following the appointment [27]. A Dual Inlet Isoprime isotope ratio mass spectrometer (Isoprime Dual Inlet IMRS; IonVantage Software, Isoprime, UK) was used to analyse urine samples to determine isotopic enrichments. Standard equations [26] were used to calculate dilution spaces for both deuterium and oxygen-18, which were then adjusted by 4 and 1%, respectively, to correct for overestimation when compared to the body water pool [28, 29]. The accuracy, therefore, of the techniques to determine total body water is excellent at approximately 4% for deuterium and 1% for oxygen-18 [28, 29], with a minimal difference between the methods. Resulting total body water values were then divided by age- and gender-specific hydration factors to give a result for FFM [30]. To account for the influence of height, FFM was adjusted to give an FFM index (FFMI; FFM/height2) [31]. Body fat was determined by subtracting the FFM value from the total body weight of the subject and converted to body fat percentage to account for weight differences between children [32].

Gross Motor Functional Ability
The gross motor functional ability for the children with CP was determined using a validated classification known as the Gross Motor Function Classification System (GMFCS) [33, 34]. This system classifies children into one of five functional levels (I–V). To enable meaningful analyses in the current study, the five levels were condensed into two groups to describe outcomes based on walking ability: children who are ambulant (GMFCS I and II – mild CP) and children who are marginally ambulant or non-ambulant (GMFCS III, IV and V – moderate-to-severe CP).

Feeding Difficulties
The oral motor and swallowing dysfunction (oropharyngeal dysphagia) of all children was objectively measured by a speech pathologist using the Feeding and Swallowing Competency Subset (Part 2) of the Dysphagia Disorders Survey – Pediatric [35], a reliable, valid tool [36]. Children were classified into four groups – no feeding difficulties, mild feeding difficulties, moderate-to-severe feeding difficulties and profound (non-oral) feeding difficulties. This outcome measure was considered as a confounding variable in the statistical analyses of dietary data.

Ethics
This study was part of a larger research project investigating the growth, nutrition and physical activity of young children with CP, which was funded by the National Health and Medical Research Council (NHMRC 569605; Australia New Zealand Clinical Trials Registry No.: ACTRN1261100616976) [23]. Ethical approvals were obtained from the Children’s Health Services District Ethics Committee (HREC/08/QCH/112/AM01 and HREC/09/QCH/124), the University of Queensland Medical Research Ethics Committee (2008002260 and 2009001869), the Cerebral Palsy League of Queensland Ethics Committee (CPLQ-2007/09-1029), the Gold Coast Health Service District Human Research Ethics Committee (HREC/09/QGC/88), the Townsville Health Service District Human Research Ethics Committee (HREC/09/QTTHS/96), the Central Queensland Human Research Ethics Committee (SSA/10/QCQ/13) and the Mater Health Services Human Research Ethics Committee (1520EC).

Power Calculations
Sample size calculations were based on the number of children required to detect a biologically and clinically significant difference between two variables of interest, for example, FFMI and energy intake. A sample size of 16 children for each group would be sufficient that a correlation of 0.5 between two variables would be statistically significant with 80% power and 5% significance. This sample size was also sufficient to identify a 1-SD difference in energy intake (i.e. 1,042 kJ) [22, 37] between the two groups as being statistically significant with 80% power and 5% significance.

Statistics
Statistical analyses were performed using Statistical Package for the Social Sciences (version 20; IBM SPSS Statistics 20.0). Children with CP were grouped according to walking ability and the fourth group consisted of the TDC. Weight and height z-scores were calculated based on age and gender using the Centers for Disease Control data [38] and incorporating the LMS (least mean square) method [39]. Measures of age, weight, height and body composition between the total population of children with CP and TDC were compared using independent t tests. Measures of age, weight and height were compared between functional ability groups and TDC using
one-way analysis of covariance (ANCOVA) correcting for age and using the Bonferroni correction for multiple comparisons. Dietary intake measures were compared between the total population of children with CP and TDC using multiple regressions, accounting for the influence of age and feeding difficulties. Dietary intake measures were compared between functional ability groups and TDC via one-way ANCOVA, accounting for the influence of age and feeding difficulties and using the Bonferroni correction for multiple comparisons. Relationships between body composition and dietary intake variables were determined using partial correlation accounting for the influence of feeding difficulties. Differences in these relationships between groups of children were established using multiple regressions.

Results

A total of 73 children with CP (70% male), mean age 2.6 ± 0.8 years (range 1.5–4.3 years) participated in this study. A total of 58% of children were born at term (n = 42), with the remaining 42% (n = 31) born preterm. Children represented all GMFCS levels (I = 39, II = 9, III = 9, IV = 7 and V = 9), and predominant motor types included spasticity (n = 60), dystonia (n = 2), athetosis (n = 3) and hypotonia (n = 8). A total of 24 children (33%) presented with no feeding problems, and 21 children (29%) with mild feeding problems. Moderate-to-severe or profound (non-oral) feeding problems were present in 28 children (37%), 19 of whom were classified as GMFCS III, IV or V. Six children were tube fed, all of whom were classified as GMFCS V. Epilepsy was present in 12 children (16%). Sixteen TDC children ranging in age from 3.0 to 4.5 years (mean 3.7 ± 0.5 years) also participated.

Log-log regression concerning energy intake and FFM for the children with CP resulted in a value of 0.96 as the power function, with a 95% confidence interval (CI) of 0.68–1.26. For the TDC, the power function was 0.92, with a 95% CI of –0.11 to 1.43. Hence, a power function of 1 was applied to express energy intake relative to FFM for all children involved in the study due to overlapping CI that included a value of 1.

For all children, results of anthropometric data, body composition, dietary intake and feeding difficulty are displayed in table 1. Overall, the children with CP were younger, (mean difference, MD = –1.1 years, 95% CI = –1.5 to –0.7 years, p < 0.001), lighter (MD = –1.0, 95% CI = –1.5 to –0.6 years, p < 0.05), and shorter (MD = –0.8, 95% CI = –1.3 to –0.3 years, p < 0.001). Children with CP had lower FFM (MD = –1.1 kg/m², 95% CI = –1.6 to –0.6, p < 0.001) and higher body fat (MD = 3.4%, 95% CI = 4.7% to 2.1%, p < 0.001) when compared to TDC. Dietary intake measures were lower in CP compared to TDC for energy intake (MD = –179 kJ/kg FFM/day, 95% CI = –257 to –102, p < 0.001) and protein intake (MD = –0.2 g/kg/day, 95% CI = –0.3 to –0.1, p < 0.001). Children with CP had lower protein intake as a percentage of energy intake (MD = –0.5%, 95% CI = –0.8 to –0.2, p < 0.001) and higher fat intake as a percentage of energy intake (MD = 3.7%, 95% CI = 5.3% to 2.1%, p < 0.001). Children with CP also had a higher prevalence of feeding difficulties (24% vs. 3%, p < 0.001).

Table 1. Anthropometric, body composition and dietary intake measures and feeding difficulties for children with CP according to gross motor functional ability and TDC

<table>
<thead>
<tr>
<th></th>
<th>Ambulant (GMFCS I/II) (n = 48)</th>
<th>Marginally ambulant/non-ambulant (GMFCS III–V) (n = 25)</th>
<th>All children with CP (n = 73)</th>
<th>TDC (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>2.6 ± 0.8^2</td>
<td>2.6 ± 0.9^4</td>
<td>2.6 ± 0.8^6</td>
<td>3.7 ± 0.5</td>
</tr>
<tr>
<td>Weight z-score</td>
<td>–0.1 ± 1.0</td>
<td>–0.1 ± 1.8^2</td>
<td>–0.4 ± 1.4^4</td>
<td>0.6 ± 0.6</td>
</tr>
<tr>
<td>Height z-score</td>
<td>–0.1 ± 1.0</td>
<td>–0.1 ± 1.3^2</td>
<td>–0.3 ± 1.1^3</td>
<td>0.5 ± 0.7</td>
</tr>
<tr>
<td>FFMI, kg/m^2</td>
<td>13.1 ± 1.5</td>
<td>11.5 ± 1.6^5, 6</td>
<td>12.6 ± 1.7</td>
<td>12.7 ± 1.0</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>18.6 ± 6.4</td>
<td>22.2 ± 10.0</td>
<td>19.8 ± 7.9</td>
<td>23.0 ± 3.6</td>
</tr>
<tr>
<td>EI, kJ/kg FFM/day</td>
<td>422 ± 82</td>
<td>367 ± 73^7</td>
<td>403 ± 83</td>
<td>397 ± 69</td>
</tr>
<tr>
<td>Protein intake, g/kg/day</td>
<td>3.1 ± 0.7</td>
<td>2.7 ± 1.2</td>
<td>2.9 ± 0.9</td>
<td>2.9 ± 0.7</td>
</tr>
<tr>
<td>Protein intake, % of EI</td>
<td>15.4 ± 3.0</td>
<td>15.5 ± 4.4</td>
<td>15.4 ± 3.5</td>
<td>15.9 ± 2.0</td>
</tr>
<tr>
<td>Fat intake, g/kg/day</td>
<td>3.1 ± 0.8</td>
<td>2.7 ± 0.9</td>
<td>3.0 ± 0.9</td>
<td>3.0 ± 1.7</td>
</tr>
<tr>
<td>Fat intake, % of EI</td>
<td>33.7 ± 7.3</td>
<td>34.5 ± 7.1</td>
<td>34.0 ± 7.2</td>
<td>31.2 ± 8.0</td>
</tr>
<tr>
<td>Feeding difficulties, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>22 (46)</td>
<td>2 (8)</td>
<td>24 (33)</td>
<td>13 (81)</td>
</tr>
<tr>
<td>Mild</td>
<td>17 (35)</td>
<td>4 (16)</td>
<td>21 (29)</td>
<td>1 (6)</td>
</tr>
<tr>
<td>Moderate to severe</td>
<td>9 (19)</td>
<td>17 (68)</td>
<td>26 (35)</td>
<td>2 (13)</td>
</tr>
<tr>
<td>Profound</td>
<td>0</td>
<td>2 (8)</td>
<td>2 (2)</td>
<td>0</td>
</tr>
</tbody>
</table>

^1 All values are means ± SDs. ^2 p < 0.05 vs. TDC (one-way ANOVA and post hoc Tukey HSD tests). ^3 p < 0.05 vs. TDC (independent t tests). ^4 p < 0.05 vs. ambulant children (one-way ANOVA and post hoc Tukey HSD tests). ^5 p < 0.05 vs. TDC (one-way ANCOVA correcting for age and using the Bonferroni correction for multiple comparisons). ^6 p < 0.001 vs. ambulant children (one-way ANCOVA correcting for age and using the Bonferroni correction for multiple comparisons). ^7 p < 0.001 vs. ambulant children (one-way ANCOVA correcting for age and feeding difficulties and using the Bonferroni correction for multiple comparisons). EI = Energy intake.
CI = –1.7 to –0.3, \( p < 0.001 \)) and shorter (MD = –0.9, 95% CI = –1.5 to –0.3, \( p = 0.004 \)) compared to the TDC. There was no difference in FFMI or body fat percentage, which could be attributed to greater numbers of ambulant children compared to marginally ambulant or non-ambulant children. There was also no significant difference in energy intake between the children with CP and TDC. Considering gross motor functional ability, as expected, significant differences in body composition and energy intake were evident between the children groups. Marginally ambulant and non-ambulant children were lighter (MD = –1.6, 95% CI = –2.4 to –0.8, \( p < 0.001 \)) and had a lower FFMI (MD = –1.6, 95% CI = –2.4 to –0.7, \( p < 0.001 \)) and a lower energy intake (MD = –70 kJ/kg FFM/day, 95% CI = –125 to –15, \( p = 0.01 \)) compared to the ambulant children. Non-ambulant children were also shorter (MD = –1.3, 95% CI = –2.0 to –0.6, \( p < 0.001 \)) and had a lower FFMI (MD = –1.5, 95% CI = –2.7 to –0.2, \( p < 0.05 \)) compared to the TDC. Ambulant children were younger than the TDC (MD = –1.1 years, 95% CI = –1.6 years to –0.6 years, \( p < 0.001 \)), but similar in all other anthropometric, body composition and dietary intake aspects. When considering the macronutrient composition of the diet, there were no significant differences between any groups of children with CP according to gross motor functional ability and TDC for protein intake or fat intake, whether this was in relation to body weight (g/kg/day) or energy intake (% of energy intake).

Marginally ambulant and non-ambulant children were further analysed to determine differences in anthropometric, body composition and dietary intake variables between children who were orally fed and those who were tube fed, as displayed in table 2. Protein intake, both relative to body weight (g/kg/day) and relative to overall energy intake (%), was significantly lower in the tube-fed children compared to the orally fed children (MD = –1.2 g, 95% CI = –2.2 to –0.1 g, \( p = 0.037 \); and MD = –4.5%, 95% CI = –8.4 to –0.7%, \( p = 0.023 \), respectively) despite a smaller sample size.

The relationships between body composition and dietary intake variables, when accounting for any feeding difficulties, were investigated. There was a significant correlation between energy intake and FFMI in all children with CP (\( r = 0.36, p = 0.002 \)), which was stronger in the TDC (\( r = 0.57, p = 0.026 \)). The relationship between energy intake and FFMI was not significantly different between these two groups of children (in terms of both the intercept and the slope of the regression line; fig. 1). In both groups, as energy intake increased, FFMI increased proportionately at the same rate. The relationship between energy intake and FFMI was not significant when considering the gross motor functional abilities of the children with CP. There were no other significant correlations be-

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**Table 2. Anthropometric, body composition and dietary intake measures for marginally ambulant and non-ambulant children (GMFCS III–V) with CP according to feeding method**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Orally fed (n = 19)</th>
<th>Tube fed (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>2.6 ± 1.0</td>
<td>2.8 ± 0.5</td>
</tr>
<tr>
<td>Weight z-score</td>
<td>–0.9 ± 1.6</td>
<td>–1.0 ± 2.2</td>
</tr>
<tr>
<td>Height z-score</td>
<td>–0.9 ± 1.3</td>
<td>–0.4 ± 1.3</td>
</tr>
<tr>
<td>FFMI, kg/m²</td>
<td>11.8 ± 1.6</td>
<td>10.6 ± 1.4</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>20.8 ± 7.6</td>
<td>26.9 ± 15.4</td>
</tr>
<tr>
<td>EI, kJ/kg FFM/day</td>
<td>376 ± 75</td>
<td>341 ± 66</td>
</tr>
<tr>
<td>Protein intake, g/kg/day</td>
<td>2.9 ± 1.2</td>
<td>1.8 ± 0.6</td>
</tr>
<tr>
<td>Protein intake, % of EI</td>
<td>16.6 ± 4.4</td>
<td>12.0 ± 2.0</td>
</tr>
<tr>
<td>Fat intake, g/kg/day</td>
<td>2.7 ± 0.8</td>
<td>2.6 ± 1.3</td>
</tr>
<tr>
<td>Fat intake, % of EI</td>
<td>33.5 ± 6.1</td>
<td>37.6 ± 9.5</td>
</tr>
</tbody>
</table>

\( ^1 \) All values are means ± SDs. \(^2 \) \( p < 0.05 \) vs. those children who were orally fed (independent t tests). EI = Energy intake.
between any body composition and dietary intake variables in the children with CP (even when considering functional ability or feeding method) or the TDC. Relationships investigated (and associated range of r values) included energy intake and body fat (in %; r = –0.02 to 0.21), protein intake (in %) and body fat (in %; r = –0.013 to 0.29), as well as fat intake (in %) and body fat (in %; r = –0.24 to 0.15).

### Discussion

The aim of this study was to determine the relationships between energy intake, macronutrient intake and body composition in preschool-aged children with CP according to gross motor functional ability and in comparison to TDC. These variables were measured using validated methods rather than extrapolated from proxy measures. The only significant established relationship in both the children with CP and the TDC was that between energy intake and FFMI, which was stronger in the TDC. There was no difference in the slopes or intercepts of the relationships between both groups. We found no significant relationships between total energy or fat intakes and percentage body fat, or protein intake and FFMI in children with CP or TDC.

Children with CP are similar to TDC in that they are partitioning energy intake to increase FFM rather than store it as body fat, due to the relationship between energy intake and FFMI. This relationship, however, was weaker in the children with CP, most probably due to the ambulatory status. The children in the current study ranged from those who were ambulant to those who were not ambulant. Children who are unable to ambulate may not increase FFM due to weight-bearing activity (independent of their total energy intake), unlike children who are marginally ambulant or ambulant.

The absence of any relationships between other dietary and body composition variables is a significant finding and is consistent with published literature concerning TDC [40–45]. This suggests that the interactions between various dietary and body composition parameters in this young age group are not considerably different from a typically developing population, and can continue to be monitored and researched using the same theoretical principles.

The macronutrient composition of the diet was similar for all children in this study, regardless of differences in energy intake. Protein and fat intake, both as a factor of body weight and as a percentage of overall energy intake, were similar across all functional levels in children with CP and reflected values seen in TDC. There were no major imbalances in the proportion of macronutrients in any group of children. Differences only emerged when considering the feeding method. The tube-fed, non-ambulant children had significantly lower protein intakes compared to those who were orally fed. These children, however, were well above the national recommended daily intake of protein based on body weight (1.8 vs. 0.91–1.08 g/kg/day depending on age) [46]. This level of protein intake is consistent with data concerning protein intakes in Australian children, which detail protein intake (relative to overall energy intake) to be, on average, 16.6% for children aged 2–3 years and 16.2% for children aged 4–8 years [47].

There was no indication of higher body fat percentages in those children who were tube fed, which has been reported as an adverse consequence of tube feeding in older, non-ambulant children with CP [10]. This result, however, could be due to the small sample size (n = 6) and further investigation is required.

Information regarding micronutrient status was not available for the current cohort, as a 3-day weighed food record is not a valid dietary assessment method to accurately assess micronutrient status in children with CP. A longer recording period coupled with blood analyses would be more appropriate [48–51]. To report the adequacy of micronutrient intake in this cohort of children would be inappropriate and misleading.

Lower FFMI in marginally ambulant and non-ambulant children compared to ambulant children and TDC were evident in the study population. At this point in time, these cross-sectional differences in body composition in preschool-aged children with CP cannot be entirely attributed to the nutrient composition of the diet. This is consistent with literature describing the links between dietary fat intake and excess adiposity and obesity in TDC. In 77 preschool-aged children (1.5–4.5 years), there was no significant relationship between fat intake and body fat percentage, despite the children being grouped into tertiles based on their percentage of dietary intake from fat [40].

Although it is evident that nutritional intervention has the potential to positively change body composition in children with CP [20], the ability to establish prospective links between dietary intake and body composition remains difficult. In adult populations, these links are evident, especially the relationship between fat intake and adiposity [52–55]. Conversely, results from well-designed, large cohort studies investigating these variables in chil-
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Children remain inconsistent and inconclusive [40–45, 56]. These relationships are difficult to elucidate in a cross-sectional study, but findings suggest that they develop over time and are not yet evident in preschool-aged children with CP.

Aspects of daily energy expenditure, in particular a child’s physical activity levels, may have a greater impact on body composition at this early age, due to the weight-bearing exercises required to increase both muscle mass and bone density [57–60]. Energy expenditure and physical activity levels of children with CP decrease as their severity of gross motor impairment increases, due to movement restrictions and limitations. These levels have been shown to be significantly lower in children with CP compared to TDC [11, 12, 18, 61]. Additionally, in a study of 32 children with CP aged between 2.9 and 4.4 years of all functional abilities, FFM and GMFCS level explained 67% of the variability in total energy expenditure [unpubl. data]. Future research should focus on investigation of total energy expenditure, in particular, physical activity levels in young children with CP using validated measures across the spectrum of gross motor functional abilities.

In conclusion, other than a relationship between energy intake and FFMI, which was stronger in the TDC when compared to the children with CP, no other links between dietary intake and body composition variables were established in this study. Further research is required to examine the longitudinal effects of macronutrient intake on body composition parameters in a cohort of children with CP. Contributing factors, such as physical activity levels, should be concurrently investigated to determine the timing and impact of nutritional and body composition changes in this population, and the effect on growth, health and development. Detailed nutritional and physical activity educational strategies can then be developed and the optimal period in which to target nutritional interventions and rehabilitation can be determined.

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