Original article

Differences in body composition according to functional ability in preschool-aged children with cerebral palsy

Jacqueline L. Walker, Kristie L. Bell, Richard D. Stevenson, Kelly A. Weir, Roslyn N. Boyd, Peter S.W. Davies

Background & aims: Altered body composition is evident in school children with cerebral palsy (CP). Fat free mass and fat mass amounts differ according to functional ability and compared to typically developing children (TDC). The extent to which body composition is altered in preschool-aged children with CP is unknown. We aimed to determine the fat free mass index (FFMI) and body fat percentage (BF%) of preschool-aged children with CP and investigate differences according to functional ability and compared to TDC.

Methods: Eighty-five children with CP (68% male) of all functional abilities, motor types and distributions and 16 TDC (63% male) aged 1.4–5.1 years participated in this cross-sectional study. Body composition was determined via isotope dilution. Children with CP were classified into groups based on their Gross Motor Function Classification System (GMFCS) level. Statistical analyses were via ANOVA, ANCOVA, post-hoc Tukey HSD tests, independent t-tests and multiple regressions.

Results: There were no significant differences in FFMI or BF% when comparing all children with CP to TDC. Children classified as GMFCS levels III, IV and V had significantly lower FFMI levels compared to children classified as GMFCS I and II (p < 0.05). Children of GMFCS IV and V had the highest mean (±SD) BF% of all children (24.6% (±10.7%)), significantly higher than children of GMFCS I and II (18.6% (±6.8%), p < 0.05).

Conclusions: Altered body composition is evident in preschool-aged children with CP, with a trend towards lower FFMI levels and greater BF% across functional ability levels from GMFCS I to V. Further research is needed to determine whether these differences are due to underlying disease processes or developmental delay.
1. Introduction

An understanding of body composition is important in clinical practice, as a measure of body composition in addition to the usual measures of height and weight is essential for the assessment of nutritional status and adequacy.1-3 This is particularly important in children with cerebral palsy (CP), where growth and nutritional status may be altered or compromised. For example, in a large study of 235 children with moderate to severe CP, aged between two and 18 years, malnutrition was characterised by low fat stores and decreased muscle mass combined with short stature. This malnutrition has then been linked with poorer health status and decreased societal participation.4 Literature detailing nutritional concerns in children with CP indicate that all children are at risk of malnutrition, regardless of the level of motor impairment.5-7 Nevertheless, the prevalence of overweight and obesity is also a concern, and is increasing in children with CP across the spectrum of functional abilities, particularly over the last decade.8

Current literature details differences in body composition that are evident in school aged and adolescent children with moderate to severe CP.4,8,9 Lower amounts of fat free mass (FFM),4-8 and either lower9,10 or similar11 amounts of body fat were apparent when compared to typically developing children (TDC). Results can be partly explained by the fact that children with CP were shorter and lighter than the TDC.4,8 When considering functional ability, a high body fat percent (BF%) was found in school aged children with severe CP classified as Gross Motor Function Classification System (GMFCS) V compared to those who were GMFCS IV.10 Studies of body composition in ambulant children with mild CP detail similar11,12 amounts of FFM combined with similar11 or greater12 amounts of body fat when compared to TDC. In comparison to children with severe CP, children with mild CP have similar amounts of body fat,13 but greater levels of FFM.14 Feeding method also affects body composition, with orally-fed children with severe CP displaying greater amounts of FFM and lower BF% when compared to those who are tube-fed.10,15

The extent to which body composition is altered in preschool-aged children with CP across the spectrum of functional abilities has not been comprehensively reported. The provision of early nutritional management strategies to a group of young children with CP has the potential to impact favourably on body composition and growth.10,16 The aim of this study, therefore, was to investigate and evaluate the differences in body composition (namely fat free mass index (FFMI) and BF%) according to functional ability (GMFCS) in preschool-aged children with CP and compare to TDC.

2. Materials and methods

2.1. Participants

Children living in the community in the state of Queensland, Australia. We defined CP as “a group of permanent disorders of movement and posture that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain”.17 The characteristic signs are spasticity, movement disorders, muscle weakness, ataxia and rigidity.18 Children with a progressive or neurodegenerative lesion, or a genetic abnormality were excluded. Typically developing children were included if they were living in Queensland, Australia at the time of the study, were in the same age range, and had no condition or were taking no medications that altered body composition. Written, informed consent was obtained from parents or legal guardians of the participants. Appointments were conducted at the closest tertiary clinical centre or at one of nine outreach locations for all children. Data were collected by the same study team at all locations throughout Queensland. Corrected age was calculated for those children under two years of age who were born at less than 37 weeks gestation to account for the influence of prematurity on growth and body composition. Chronological age was used for all other children. Data regarding birth weight and gestational age were collected via physician interview, parent report or retrospective chart review.

2.2. Body composition

Body composition was measured non-invasively using one of two stable isotope dilution procedures: deuterium19 for the majority of children (n = 72 children with CP) or oxygen-18 (n = 13 children with CP and all 16 TDC).20 This was due to a small subset of the children with CP and all TDC being involved in a concurrent study investigating total energy expenditure. Children were given a dose of deuterium or oxygen-18 in the form of water, either orally or via a feeding tube. Caution was taken to ensure that any spillage was collected in a cloth which was weighed before and after dosing to determine how much fluid was lost. Prior to consumption of the dose, a single urine sample was collected to determine natural baseline enrichments of the isotopes in the body. For the deuterium-dilution technique, a second urine sample was collected at approximately five hours after dosing.19 When using oxygen-18, daily samples were collected for the 10 days following the appointment.20 Parents of children with poor or no bladder control were instructed to collect samples using either urine bags or absorbent cotton wool balls placed in the nappy, from which urine was extracted. All urine samples were analysed using a Dual Inlet Isoprime isotope ratio mass spectrometer (Isoprime Dual Inlet IMRS — IonVantage Software, Isoprime, Manchester, UK) to determine isotopic enrichments. Dilution spaces for both deuterium and oxygen-18 were calculated according to standard equations,19 and adjusted by 4% and 1% respectively to correct for overestimation when compared to the body water pool and give consistent total body water measures.20,21 The subsequent total body water values were divided by age and gender specific hydration factors to give a result for FFM.21 To account for the influence of height, FFM was adjusted to give an FFMI (FFM/height2).22 Body fat was determined by the difference in FFM and total body weight. Body fat percent was calculated to account for weight differences between children.
2.3. Gross motor functional ability

Gross motor functional ability for the children with CP was determined independently by two research physiotherapists, using an internationally accepted and validated classification, the GMFCS.27 Children were classified into one of five functional categories (I–V), which were then condensed into three groups: GMFCS I and II, GMFCS III and GMFCS IV and V.

2.4. Anthropometry

Weight was measured to the nearest 100 g using portable electronic scales (Homemaker Ltd, Australia) or chair scales (Seca Ltd, Germany). If the child was unable to stand or sit on their own, they were weighed together with a parent. The parent was then weighed separately and this weight subtracted from the combined weight to obtain a value for the child. Height or length (for children under two years of age or those unable to stand correctly) was measured to the last completed millimetre using a portable length measuring board (Short Productions, Maryland, USA). In children where a direct measure of height or length was not possible, knee height was measured to the last completed millimetre with an anthropometer (Holtain Ltd, Dyfed, UK). Knee height was then used to predict height using published, validated equations developed previously from a population of children with CP.5 All measurements were taken by one of three trained dietitians.

2.5. Ethics

This study was conducted as part of a larger project investigating the growth, nutrition and physical activity of preschool-aged children with CP (funded by the National Health and Medical Research Council (NHMRC) 569605) (Australian New Zealand Clinical Trials Registry (ANZCTR) number: ACTRN12611000616976).24 Ethical approval for this study was obtained from the Children’s Health Services District Ethics Committee (HREC/08/QRCH/112/AM01 and HREC/09/QRCH/124), The University of Queensland Medical Research Ethics Committee (2008002260 and 2009001869), the Cerebral Palsy League of Queensland Ethics Committee (CPLQ-2000/2010-1029), 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/QTHS/96), the Central Queensland Human Research Ethics Committee (SSA/10/QCQ/13), and the Mater Health Services Human Research Ethics Committee (1520EC).

2.6. Power calculations

Using data from a previous study which investigated BF% in 77 TDC aged between 1.5 and 4.5 years, 1-SD of BF% was taken as 6%.25 In order to detect a 6% difference between groups in the current study, a total of 16 children with CP for each functional ability group and 16 TDC were required, which was statistically significant with 80% power and 5% significance. A 1-SD difference was concluded to be biologically and clinically significant, as this represents the difference between a child classified in the 16th percentile compared to the 50th percentile, or the 50th percentile compared to the 84th percentile.

2.7. Statistical analyses

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) Version 20 (IBM SPSS Statistics 20.0). Children with CP were grouped according to functional 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 data26 and incorporating the LMS method. Measures of age, weight and height were compared between all children with CP and the TDC via independent t-tests. Measures of age, weight and height were compared between functional ability groups and TDC using one-way ANOVA and post-hoc Tukey HSD tests to adjust for multiple comparisons. Body composition measures (FFMI and BF%) were compared between all children with CP and TDC via multiple regression, correcting for the influence of age. Body composition measures (FFMI and BF%) were compared between functional ability groups and TDC using one-way ANCOVA, correcting for the influence of age and using the Bonferroni correction for multiple comparisons.

3. Results

A convenience sample of 85 children with CP (68% male) with a mean age (±SD) of 2.6 (±0.8) years participated in the study. Children ranged in age from 1.5 to 4.2 years. The distribution of GMFCS levels was as follows: I = 42, II = 10, III = 13, IV = 9, V = 11, and with the exception of the inclusion of slightly more children classified as GMFCS I, is representative of a larger population of children with CP.27 Predominant motor impairments were: spasticity (n = 72), dystonia (n = 2), athetosis (n = 3) and hypotonia (n = 8). Feeding method was via tube in 7 children (8%), all of whom were classified as GMFCS IV or V. Epilepsy was present in 15 children (18%), the majority of whom were classified as GMFCS III, IV or V (n = 11, 73%). The comparison group consisted of a convenience sample of 16 TDC (63% male) with a mean age of 3.7 (±0.5) years, range 3.0–4.5 years. All children were in good health at the time of the study.

Descriptive data are included in Table 1. The use of z-scores accounted for the differences in gender and age. Children with CP were younger, lighter and shorter than the TDC (p < 0.05). Children classified as GMFCS III and GMFCS IV and V had lower weight and height z-scores respectively when compared to those who were GMFCS I (p < 0.02). There were no differences, however, in weight and height z-scores between children classified as GMFCS III and those who were GMFCS IV and V.

Body composition measures for all groups of children are detailed in Table 2. Overall there were no significant differences in FFMI or BF% between the children with CP and the TDC after accounting for differences in age. Children classified as GMFCS III had significantly lower FFMI and FFMI values when compared to those who were GMFCS I (p < 0.02). There was a trend towards lower FFMI and FFMI when compared to TDC (MD = 1.2 kg and –1.3 kg/m² respectively, p < 0.05) despite smaller sample sizes than predicted due to recruitment difficulties. Children classified as GMFCS IV and V had similar values for all body composition parameters when compared to children classified as GMFCS III.

Children classified as GMFCS IV and V had the lowest values of FFMI (significantly lower than both those who were GMFCS I and II (MD = -1.5 kg/m², p < 0.002) and TDC (MD = -1.5 kg/m², p < 0.002)) and highest BF% of all children involved in the study (significantly higher than children of GMFCS I and II (MD = 5.6%, p = 0.026)). Overall there was a trend towards lower FFMI (r = -0.4, p = 0.00) and greater BF% (r = 0.3, p = 0.008) cross-sectionally across GMFCS levels from I to V, accounting for differences in age of the children. The GMFCS level or functional ability of a child contributed to 16% of the variability in FFMI, independent of the influence of age (p < 0.001). The contribution of GMFCS level to BF% was minimal at 8%. Subsequent analysis of all data in Tables 1 and 2 excluding those children who were partially or completely tube-fed did not significantly alter any outcomes and produced similar results.
When considering the feeding method of the children with severe CP (Table 3), there was a trend toward lower FFMI (p = 0.07) for those children who were tube-fed compared to orally-fed, despite no difference in age. This result, however, was not statistically significant.

4. Discussion

The aim of this study was to investigate and evaluate the differences in body composition according to gross motor functional ability in preschool-aged children with CP and compare to TDC. In the absence of validated measures to accurately estimate body composition in the clinical setting, assessment of body composition in children with CP remains difficult. A variety of anthropometric measures (for example weight-for-height and skinfold thicknesses) have been shown to be poor predictors of BF% when compared to direct techniques or DXA as per the current study. When considering the feeding method of the children with severe CP,6,7 particularly in those with greater functional impairment who energy requirements, did not result in adverse effects on body composition.4,6,7 Evidence suggests that body composition of children with CP is greatly altered in those with moderate to severe CP.9 It is beneficial to measure body composition via a criterion standard such as isotope dilution techniques or DXA as per the current study.

As an overall population, findings regarding similar amounts of FM and BF% when compared to TDC are consistent with previous literature.5,11,14 This study, however, has also described differences between preschool-aged children of varying functional levels. Altered body compositions were evident in this young age group across the spectrum of functional abilities, particularly in those children who were classified as GMFCS IV and V. The trend towards lower FFMI and greater BF% with declining gross motor functional ability reaches statistical significance in those children who were classified as GMFCS III or GMFCS IV and V. This is despite no significant differences in height and weight z-scores between children who were classified as GMFCS III and those who were GMFCS IV and V, attributed to large standard deviations in the GMFCS IV and V group. This indicates the inclusion of children of varying body sizes at either extremes, with individual height and weight z-scores ranging from –3.11 to 2.36 and –4.87 to 3.07 respectively. Children classified as GMFCS IV and V have changes in body composition that have the potential to persist throughout childhood and impact negatively on their overall health if the trend continues. Health concerns may include the development of cardiovascular, respiratory and musculoskeletal problems, and a decrease in functional status (incorporating mobility and the ability to complete self-care tasks).28

A major factor that is hypothesised to contribute to the current study results is the GMFCS level of the children and their resulting physical activity levels. Although physical activity was not reported in the current study, children with greater functional impairment and hence activity limitations may not increase FFM due to reduced levels of physical activity, unlike their counterparts who are less restricted (those children classified as GMFCS I, II and III). The total amount of physical activity appears to be an important factor, as FFMI increases as functional ability improves, to the point where children classified as GMFCS I and II have similar levels of FFMI to TDC.

Previous literature reported that overfeeding tube-fed children who were classified as GMFCS IV and V (median age 9.0 years) relative to their estimated energy requirements resulted in increased amounts of body fat.13 Further investigations determined that the use of a low-energy enteral feed in a similar population, the prescribed volume of which did not exceed 75% of estimated energy requirements, did not result in adverse effects on body composition.13 Whether a higher relative fat intake contributes greatly to increases in BF%, especially in children classified as GMFCS IV and V who are orally-fed, independent of energy intake, is yet to be determined. The trend towards greater BF% and absolute body fat in all children of GMFCS IV and V in the current study, regardless of feeding method, is clinically important. A tendency towards adiposity is a risk factor for the development of obesity, which is now a health concern amongst all children with CP,6,7 particularly in those with greater functional impairment who

### Table 1

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>GMFCS I and II (n = 52)</th>
<th>GMFCS III (n = 13)</th>
<th>GMFCS IV and V (n = 20)</th>
<th>All children with CP (n = 85)</th>
<th>TDC (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>2.63 ± 0.79a</td>
<td>2.04 ± 0.47b</td>
<td>2.94 ± 0.86c</td>
<td>2.61 ± 0.81d</td>
<td>3.69 ± 0.48</td>
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<td>Weight z-score</td>
<td>−0.1 ± 1.0</td>
<td>−1.2 ± 1.3d</td>
<td>−1.1 ± 1.9e</td>
<td>−0.5 ± 1.4f</td>
<td>0.6 ± 0.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>91.2 ± 7.5g</td>
<td>83.2 ± 5.1h</td>
<td>89.8 ± 7.5i</td>
<td>89.6 ± 7.7i</td>
<td>101.9 ± 5.3</td>
</tr>
<tr>
<td>Height z-score</td>
<td>1.0 ± 1.1</td>
<td>1.0 ± 1.1</td>
<td>1.0 ± 1.3</td>
<td>−0.4 ± 1.2</td>
<td>0.5 ± 0.7</td>
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<tr>
<td>Tube-fed (n)</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>2641 ± 1207</td>
<td>1841 ± 853</td>
<td>2344 ± 1291</td>
<td>2471 ± 1206</td>
<td>NA</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>36.0 ± 4.9</td>
<td>30.2 ± 4.3</td>
<td>36.0 ± 5.3</td>
<td>35.1 ± 5.3</td>
<td>NA</td>
</tr>
</tbody>
</table>

### Table 2

| Body composition measures for children with cerebral palsy according to gross motor functional ability and typically developing children. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| | GMFCS I and II (n = 52) | GMFCS III (n = 13) | GMFCS IV and V (n = 20) | All children with CP (n = 85) |
| FFM (kg) | 11.0 ± 1.5 | 9.0 ± 1.5 | 9.6 ± 1.9 | 10.4 ± 1.8 |
| FFMI (kg/m²) | 13.0 ± 1.5 | 11.8 ± 1.9 | 11.4 ± 1.4 | 12.4 ± 1.7 |
| Body fat (kg) | 2.7 ± 1.4 | 2.1 ± 1.4 | 3.4 ± 2.0 | 2.8 ± 1.5 |
| Body fat (%) | 18.6 ± 6.8 | 19.1 ± 7.1 | 24.6 ± 10.1 | 20.1 ± 8.1 |

CP: cerebral palsy; GMFCS: Gross Motor Function Classification System; TDC: typically developing children.

- All values are means ± SDs.
- Significantly different from the TDC (p < 0.05) by one-way ANOVA and post-hoc Tukey HSD tests.
- Significantly different from the GMFCS III group (p < 0.05) by one-way ANOVA and post-hoc Tukey HSD tests.
- Significantly different from the GMFCS I and II group (p < 0.001) via independent t-tests.
- Significantly different from the GMFCS I and II group (p < 0.05) by one-way ANOVA and post-hoc Tukey HSD tests.
are unable to ambulate. Further research is required to link dietary intake to body composition in this young age group.

Another dietary factor that could influence body composition is the early nutrition of a child, particularly the duration of exclusive, and any, breastfeeding. Although this was outside the scope of the current study and not investigated, differences in breastfeeding practices between groups of children may help explain differences in body composition in the preschool years.

A limitation of the current study is the fact that data regarding birth weight were not available for the TDC, therefore comparisons to children with CP were not able to be made. Differences in birth weight (combined with other post-natal events and nutritional interventions such as fortified feeding, complementary feeding and timing of the introduction of solids) may contribute to differences in body composition at a later preschool age and should be considered in future research.

Due to a paucity of data, it is not yet clear how the body composition of children classified as GMFCS III develops over time, and if they are more similar to children who are GMFCS I and II, those who are GMFCS IV and V, or have differing characteristics altogether. These children have not been previously investigated as a separate group. Our results regarding differences in body composition highlight children classified as GMFCS III as a group that requires more intensive investigation and indicates that there is the potential to intervene early to prevent these children developing excessive levels of body fat and lower FFMI levels.

Although these children had BF% that were slightly higher than children of GMFCS I and II but lower than TDC, results were not significantly different. Conversely, FFMI levels were already lower in children of GMFCS III when compared to those who were GMFCS I or II. Nutritional monitoring and interventions have not routinely focused on children who are classified as GMFCS III, who may potentially benefit from increased input and review.

Considering current results, we conclude that altered body composition is a secondary health concern in children with CP that is part of the natural development of the motor disorder. Our findings of lower FFMI and higher BF% even in very young children with CP, close to diagnosis, support this notion. It is clear that these differences are not developing over an extended period of time, and are evident from a young age. Distinctions between the gross motor function levels and socio-economic conditions, and which of these factors impact of targeted, early interventions (both dietary and physical activity/therapy) on a child’s body composition, and how these interventions can be best used to maximise positive outcomes that are linked with improvements in overall health, participation and quality of life.

In conclusion, changes in body composition are evident in preschool-aged children with CP. Altered body composition makes interpretation of growth and nutritional status difficult, particularly when it remains unclear as to what constitutes optimal FFM and body fat levels relative to functional ability level in this population and their relationship to general health and wellbeing. Future research is required to determine this, and also to investigate contributing factors such as dietary intake and physical activity levels. Results indicate the potential to improve the body composition of preschool-aged children with CP with the provision of appropriate early intervention strategies, especially in those children who are classified as GMFCS III, IV and V.

Nutritional assessment, intervention and monitoring (including body composition) needs to be targeted to a younger age group, and preferably considered in the overall management plan from diagnosis.

Statement of authorship

The author’s responsibilities were as follows: KLB, RDS, KAW, RNB and PSWD designed research; JLW and KLB conducted research; RNB and PSWD provided essential materials; JLW analysed data and performed statistical analyses; JLW wrote the paper; and JLW, KLB, RDS, KAW, RNB and PSWD reviewed and approved the final content. All authors have read and approved the following manuscript, and all qualify for authorship.

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Conflict of interest statement

The authors have no conflicts of interest to disclose.

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**Table 3**

<table>
<thead>
<tr>
<th>Anthropometric and body composition measures for children with cerebral palsy classified as GMFCS IV and V according to feeding method.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orally-fed (n = 13)</td>
</tr>
<tr>
<td>Age (year)</td>
</tr>
<tr>
<td>Weight z-score</td>
</tr>
<tr>
<td>Height z-score</td>
</tr>
<tr>
<td>FFMI (kg/m²)</td>
</tr>
<tr>
<td>Body fat (%)</td>
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</tbody>
</table>

FFMI, fat free mass index.

*All values are means ± SDs, statistical analyses via independent t-tests.*
References