Validation of a modified three-day weighed food record for measuring energy intake in preschool-aged children with cerebral palsy

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1. Introduction

Cerebral palsy (CP) remains the most common cause of physical disability in childhood, occurring in between 2 and 3 infants per 1000 live births in industrialised nations. 1 Children with CP often grow differently compared to their typically developing peers in terms of both height and weight, and it has been reported that a significant contributor to this altered growth is poor nutritional status, due to inadequate dietary intake. 2 Consequently, measurement and quantification of energy intake (EI) are essential for appropriate nutritional management, and can assist in determining causes and contributors of both under and over nutrition. Accurate assessment of EI should also be a priority when investigating relationships between diet, total energy expenditure (TEE), nutritional status and other parameters of interest such as health outcomes. This ensures that any conclusions drawn are meaningful, reliable and valid.

In a state of weight balance, an individual’s TEE is equivalent to their EI. 3 The doubly labelled water (DLW) technique is a gold standard measure that can be used to estimate TEE in children in free-living conditions. 4,5 Use of the DLW method allows for reported EI to be compared to an accurate reference standard, hence it is the desired approach to use when validating dietary assessment methods. 6 Only one previous study has investigated the validity of a three-day weighed food record in this manner in a population of
children with CP. In this study, significant overestimations of EI (44–54%) in a group of 32 children with severe spastic quadriplegic CP aged between 2 and 18 years were reported by Stallings et al. A difference of only 2% between EI and TEE in the control group indicated accurate reporting. Considerable feeding difficulties in the children with CP and resultant food loss were hypothesised to have contributed to these findings. These conclusions reinforce that food records are a valid tool for determining EI in typically developing children (TDC), but their use in a population of children with CP is questionable.

The aim of the current study was to validate the use of a modified three-day weighed food record for measuring EI in a population of young children with CP. This will have important implications when determining the EI of this group.

2. Materials and methods

2.1. Participants

Children living in the community in the state of Queensland, Australia were invited to participate. Children were included if they had a diagnosis of CP, were aged between 35 and 54 months (chronological age), were of any functional ability level, and were living in Queensland, Australia. Participants were excluded if they had a progressive or neurodegenerative lesion, or a chromosomal or genetic abnormality known to impact on growth, energy expenditure or body composition. Typically developing children in the same age range residing in Queensland, Australia, were also invited to participate. Children were excluded if they had any conditions or were taking any medications that altered energy metabolism or body composition. Written, informed consent was obtained from parents or legal guardians of the children. Appointments were at the Royal Children’s Hospital, Brisbane, Australia, or the closest outreach hub location. The same study team visited the nine geographic locations throughout Queensland to collect data.

2.2. Anthropometry

Measurements were conducted by one of three trained dietitians. Weight was measured to the nearest 100 g on portable electronic scales (Homemaker Ltd, Australia). If the child could not stand on their own, they were weighed together with a parent on the scales. The parent was then weighed separately and this weight subtracted from the combined weight to obtain a value for the child. Height or length (if the child was unable to stand) was measured to the last completed millimetre with an anthropometer (Holtain Ltd, Dyfed, UK), was used as a proxy measure for height in children where a direct measure was not possible, using validated equations developed previously from a population of children with CP.

2.3. Functional ability

The gross motor ability of each child was determined by two research physiotherapists using the Gross Motor Function Classification System (GMFCS), an internationally accepted and validated measure. The GMFCS classifies children with CP on the basis of gross motor functional abilities and limitations, and includes five levels: I (includes children who are most able) to V (children who are least able), and four age bands (less than 2 years old, from 2 to 4 years, from 2 to 6 years and from 6 to 12 years). The five levels represent differences in gross motor function that are thought to be meaningful in the daily lives of children with CP, such as locomotion, sitting ability and balance. The age bands allow for age-related differences in gross motor function. Children were classified into one of five functional categories, which was then condensed into two groups to described outcomes based on the severity of impairment: children with mild CP (GMFCS I and II — ambulant), and children with moderate to severe CP (GMFCS III–V — marginally-ambulant and non-ambulant).

2.4. Energy intake assessment

Parents completed a three-day weighed food record for their child, detailing all food and fluids consumed over two weekdays and one weekend day. They were provided with kitchen scales accurate to 0.1 g and a paper-based three-day food record. 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 (including vomiting and regurgitation) to obtain specific amounts actually consumed by their child. This was done to ensure more accurate results that accounted for any feeding difficulties. Parents were also encouraged to include the brand names of foods and fluids, any recipes used, and provide details on cooking method. Parents were required to complete the food diary within the 10 day time frame for the measurement of TEE. Food records were coded and analysed by one research dietitian using the Foodworks™ dietary analysis software (Xyris Software, Australia 2009). Any inconsistencies in records were checked extensively with parents via telephone before analysis. Final calculations of mean EI (kJ/day) for each child was weighted according to the days recorded. The two weekdays had a significantly greater impact upon the mean EI value when compared to the one weekend day, due to the fact that they represent 5/7 of a weekly EI value.

2.5. Intra-rater reliability

A random sample of 10 children (two from each Gross Motor Function Classification System (GMFCS) level) was chosen to determine inter-rater reliability of analysis of food records. The one rater coded and analysed each food diary on two separate occasions, with the time frame between first and second analysis of a food diary being seven months to 2 years. The agreement between the weighted EI values from the first and second occasions were compared using Bland and Altman analyses.

2.6. Total energy expenditure

The DLW technique was used to measure TEE. Each child was required to consume a loading dose of deuterium and oxygen-18 in the form of water, dependent on body weight (1.25 g/kg of 10% H218O and 0.05 g/kg of 100% 2H2O) either orally or via a feeding tube. Parents were required to collect a single urine sample from their child prior to dosing to determine natural baseline enrichment of the isotopes in the body. Daily samples were required thereafter for 10 days. Collection of samples from children with poor or no bladder control was via the use of urine bags or absorbent cotton wool balls placed in the nappy, from which urine was extracted. All samples were analysed to determine isotopic enrichments using a Dual Inlet Isoprime isotope ratio mass spectrometer (Isoprime Dual Inlet IMRS – IonVantage Software, Isoprime, Manchester, UK). Results were expressed relative to the international standard, Vienna Standard Mean Ocean Water. Dilution spaces for both deuterium and oxygen-18 were calculated according to standard equations. Rate constants were determined via the multipoint method, which
involved calculating the coefficient of the regression line of the natural logarithm of enrichment over time. The production rate of carbon dioxide was calculated as the difference between the elimination rates of deuterium and oxygen-18 in conjunction with their dilution space and accounting for isotopic fractionation. Oxygen consumption was determined by assuming a respiratory quotient of 0.85 and TEE was calculated according to the abbreviated Weir equation.

2.7. Validation of the modified three-day weighed food record

The three-day weighed food record was validated by comparing reported EI to measures of TEE for each individual child. A state of weight balance for each child was assumed over the 10 day data collection period. Consequently, EI was assumed to match a child’s energy requirements for weight maintenance during the data collection period. Typical within-subject variability in day-to-day EI routinely seen in young children’s diets is approximately 19% at the group level. Reporting of EI in the current study, therefore, was accepted to be valid at the group level if the mean difference between reported EI and measured TEE (when expressed as a percentage of TEE, referred to as bias) was less than 19%. The ratio of EI to TEE was determined for each individual child, and, at the group level, represents the degree of under or over reporting.

2.8. Feeding difficulties

Objective measurement of oral motor and swallowing dysfunction was rated using the Feeding and Swallowing Competency Rating Scale (Paediatric). A reliable, valid tool. A speech pathologist classified children into groups — no feeding difficulties, mild feeding difficulties, moderate to severe feeding difficulties and profound (non-oral) feeding difficulties.

2.9. Ethics

Ethical approval for this study was obtained from the Children’s Health Services District Ethics Committee (HREC/09/QCH/124) and The University of Queensland Medical Research Ethics Committee (2009001869).

2.10. Statistics

Statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) Version 20 (IBM SPSS Statistics 20.0). Children with CP were grouped according to their level of functional ability — mild CP (GMFCS I and II — ambulant) and moderate to severe CP (GMFCS III, IV and V — marginally-ambulant or non-ambulant). The third group consisted of age matched TDC. Weight and height z-scores were calculated based on age and gender using the Centers for Disease Control data and incorporating the LMS method. All variables were normally distributed within each group, with the exception of age. Measures of weight, height, weight z-scores and height z-score were compared between groups using independent t-tests. Measures of age were compared between groups using Mann-Whitney U tests. Measures of EI and TEE were compared using paired t-tests, Bland and Altman analyses and independent t-tests.

3. Results

3.1. Subject characteristics

Thirty-one children with CP (61% male) ranging in age from 2.9 to 4.4 years participated. Children with CP represented all GMFCS levels (I = 13; II = 2; III = 5; IV = 3; V = 8), motor types (spasticity = 25, dystonia = 2, athetosis = 3 and hypotonia = 1) and gross motor distributions (hemiplegia = 10, diplegia = 7, triplegia = 4 and quadriplegia = 10). Thirteen children (42%) had moderate to severe or profound feeding problems when objectively rated by a speech pathologist. Eleven of these children were classified as GMFCS III, IV or V. Six children (19%) were tube-fed, all of whom were classified as GMFCS level V. Epilepsy was present in six children (19%), five of whom were classified as GMFCS IV or V. The comparison group consisted of 15 TDC (63% male) ranging in age from 3.0 years to 4.5 years.

General anthropometric measures and subject characteristics for all children are shown in Table 1. As an overall population, the children with CP were shorter and lighter than the TDC. When considering functional abilities, those children with mild CP weighed significantly less than the TDC, however no difference was found concerning height. Children with moderate to severe CP were significantly shorter and lighter than the TDC, however only height scores were significantly lower when compared to children with mild CP. Secondary analysis of all results in Table 1, excluding those children who were tube-fed, did not significantly alter any outcomes and produced similar values.

3.2. Intra-rater reliability for energy intake

Food records from a subset of 10 children (60% male), mean age 3.6 (±0.6) years, representing all GMFCS levels (I = 2; II = 2; III = 2; IV = 2; V = 2) were used to assess reliability of coding and analysis. Intra-rater reliability was established at 0.4% difference in EI at the population level. The difference in EI between first and second analysis at an individual level was less than 6% for records of all children.

### Table 1

<table>
<thead>
<tr>
<th>Anthropometric measures for children with cerebral palsy according to gross motor functional ability and typically developing children.</th>
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<tbody>
<tr>
<td><strong>Children with mild CP (n = 15)</strong></td>
</tr>
<tr>
<td><strong>Age (y), median (IQR)</strong></td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
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<tr>
<td><strong>Height (cm)</strong></td>
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<td><strong>Height z-score</strong></td>
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*IR; interquartile range.

**All** values are means ± SDs, unless otherwise specified.

*b* significantly different from the typically developing children (p < 0.05) via independent t-tests.

*c* significantly different from children with moderate to severe CP (p < 0.05) via independent t-tests.
3.3. Comparison of reported energy intake to total energy expenditure data

Results regarding comparisons of EI to TEE are presented in Table 2. The measurement of TEE via the DLW method succeeded in all subjects. Energy intake values were statistically significantly less than TEE values for the children with CP as a total population and for the TDC. When considering functional ability, EI values were significantly less than TEE values for children with mild CP but not for those with moderate to severe CP. When evaluating the difference in EI as a percentage of TEE for each group, children with moderate to severe CP demonstrated the most accurate reporting with a result of 4.3%. Children with mild CP (14.8%) showed similar results to the TDC (16.8%). Differences in the bias between groups were only significant when comparing the children with moderate to severe CP to TDC. The bias was consistent across the range of measurements for all groups of children except those with mild CP. The correlation within this group between the mean of EI and TEE and the difference reached statistical significance (r = 0.62, p < 0.05). This indicated that under-reporting was more frequent in

<table>
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<th>Children with mild CP (n = 15)</th>
<th>Children with moderate to severe CP (n = 16)</th>
<th>All children with cerebral palsy (n = 31)</th>
<th>Typically developing children (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EI (kJ/day)</td>
<td>5121 ± 1368b</td>
<td>4165 ± 1136</td>
<td>4628 ± 1325c</td>
<td>5310 ± 864c</td>
</tr>
<tr>
<td>TEE (kJ/day)</td>
<td>5979 ± 953</td>
<td>4359 ± 1000</td>
<td>5142 ± 1265</td>
<td>6397 ± 779</td>
</tr>
<tr>
<td>Bias (%)</td>
<td>14.8</td>
<td>4.3</td>
<td>10.0</td>
<td>16.8</td>
</tr>
<tr>
<td>Limits of agreement (kJ)</td>
<td>−2559 to 845</td>
<td>−1552 to 1165</td>
<td>−2117 to 1138</td>
<td>−2524 to 350</td>
</tr>
<tr>
<td>Ratio of EI:TEE</td>
<td>0.85 ± 0.15</td>
<td>0.96 ± 0.14d</td>
<td>0.91 ± 0.15</td>
<td>0.83 ± 0.11</td>
</tr>
<tr>
<td>Children with EI values within 20% of TEE values (n, %)</td>
<td>10 (67)</td>
<td>13 (81)</td>
<td>23 (74)</td>
<td>9 (60)</td>
</tr>
</tbody>
</table>

EI, energy intake; TEE, total energy expenditure.

* All values are means ± SDs unless otherwise specified.
* b Significant correlation between the mean of the reported energy intake and measured total energy expenditure and the difference (p < 0.05) by Pearson’s correlation.
* c Significantly different from TEE (p < 0.01) via paired t-tests.
* d Significantly different from typically developing children (p < 0.01) by paired test.

Fig. 1. Bland and Altman plots of the difference between reported energy intake via a three-day weighed food record and measured total energy expenditure via the reference method for (a) children with mild cerebral palsy (Gross Motor Function Classification System (GMFCS) I and II) (n = 15); (b) children with moderate to severe cerebral palsy (GMFCS III, IV and V) (n = 16); (c) typically developing children (n = 15).
children with lower intakes, compared with over reporting, which rises with increasing intake. The corresponding Bland and Altman plots for each group of children can be seen in Fig. 1.

The ratio of EI to TEE was also calculated for each group to compare under and over reporting with a previously published study7 (Table 2). Results showed no substantial over reporting for any one group at the population level as indicated in previous literature.7 When considering functional ability, the ratio of 0.96 for children with moderate to severe CP indicated greater accuracy in group reporting when compared to the TDC (0.83).

The children with moderate to severe CP were further examined to determine the influence of feeding method on the accuracy of reporting (Table 3). Children who were orally-fed displayed more accurate reporting when compared to those who were tube-fed, evidenced by a very low difference in reported EI and measured TEE and an EI to TEE ratio of 1.01 indicating nearly perfect reporting. The corresponding Bland and Altman plots for both groups of children are displayed in Fig. 2.

4. Discussion

Comparisons of EI to TEE data indicate that at a population level, the modified three-day weighed food record is a valid tool to measure EI in preschool-aged children with CP across all functional ability levels and a variety of motor types. Accurate reporting was evident amongst all groups. When considering the mean difference between reported EI and measured TEE as a percentage of TEE (bias), all values were minimal and representative of typical within-subject variability in day-to-day energy intake routinely seen in young children’s diets.23

Reporting of EI was most accurate in the children with moderate to severe CP, particularly those who were orally-fed when compared to children who were tube-fed. This important finding is in contrast to previous literature by Stallings et al.7 Their results of gross overestimation of EI in school-aged children (mean age 10.3 yrs) are not supported by data in the current study, which indicates only minimal under reporting (4%). Although no Bland and Altman analyses or paired t-tests were performed by Stallings et al.,7 results have been broadly accepted and reported in later literature.24-26 No further studies have attempted to replicate the findings in other populations of children with CP of varying ages, functional abilities or motor types. This is understandable given the technical expertise required when using the DLW method. The contrasting yet clinically significant results obtained in the current study could be attributed to a number of factors. The modifications made to the three-day weighed food record by an experienced dietitian incorporated problems associated with feeding abilities, such as food and fluid spillage, so that data reflected actual ingestion of foods and hence EI. The increased awareness and focus of parents on dietary intake in a young age group susceptible to nutritional concerns is also an important factor to consider. Parents of orally-fed children (with or without associated feeding difficulties) could potentially have greater levels of stress when feeding their child. This increased focus on foods consumed then translates to more accurate reporting. Conversely, the major nutritional concerns of children who are tube-fed have been identified, and parental focus may be on other concerns.

Reporting for the children with mild CP was similar to that for the TDC, however both groups displayed a greater amount of under reporting when compared to the children with moderate to severe CP. A simple contributor to these results may be that children with mild CP are more mobile, and have the potential to consume and discard food and fluid items without parental knowledge. Parents of children with mild CP may consider that their child has minimal feeding difficulties and the perceived importance of nutritional monitoring is less. In addition, current national health policies and

### Table 3

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<thead>
<tr>
<th>EI (kJ/day)</th>
<th>TEE (kJ/day)</th>
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<tbody>
<tr>
<td>Children who were orally-fed (n = 10)</td>
<td>4545 ± 1046</td>
</tr>
<tr>
<td>Children who were tube-fed (n = 6)</td>
<td>4526 ± 874</td>
</tr>
<tr>
<td>Bias (%)</td>
<td>0.4</td>
</tr>
<tr>
<td>Limits of agreement (kJ)</td>
<td>-1373 to 427</td>
</tr>
<tr>
<td>Ratio of EI:TEE</td>
<td>1.01 ± 0.14&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Children with EI values within 20% of TEE values (n, %)</td>
<td>9 (90)</td>
</tr>
</tbody>
</table>

EI, energy intake; TEE, total energy expenditure.

<sup>a</sup> Significantly different from TEE (p < 0.05) via paired t-test.

<sup>b</sup> Significantly different from those children who were tube-fed (p < 0.05) by independent t-test. Correlations between the mean of the reported energy intake and measured TEE and the difference were not statistically significant for either group.
media messages concerning obesity could influence parents to give socially desirable answers. Minimal under reporting in the TDC may also have been the result of varying levels of parental motivation, as this study did not specifically focus on outcomes for TDC. The inconsistent bias seen in children with mild CP will need to be further investigated within a larger sample size.

Results show that the three-day weighed food record may be of use in individual children. On average, 75% of the children with CP had EI results that were within 20% of their TEE values. When considering that day-to-day EI in young children is known to vary by up to 19%, this modified food record has the potential to be a useful tool in clinical situations when used in combination with regular growth monitoring. This must be done with caution and clear clinical judgement, however, as the Bland and Altman plots in Figs. 1 and 2 show wide limits of agreement, particularly for the children with mild CP.

The small sample size and limited number of children with dystonia and athetosis motor types is a limitation of the current study. Unfortunately this is difficult to overcome due to the expenses associated with the DLW technique, combined with data collection challenges and reduced frequency of these motor types. Another limitation of the study was the assumption regarding weight balance, as children were not weighed after the data collection period. Any weight changes, however, were assumed to be minimal and would not impact greatly on the validity of results.

Outcomes from this study present a number of further recommendations for upcoming research and practice. Cross-validation of the diary in other CP populations, specifically older children, is encouraged. Incorporation of the diary into daily clinical practice would enable determination of the utility and practicality of the method in a clinical environment when compared to a research setting.

In conclusion, our criterion validation study is the first to confirm that a modified three-day weighed food record accurately measured EI in preschool-aged children with CP. It is a valid tool that can be used for children across all GMFCS levels, motor types and a range of feeding abilities. Accurate determination of EI in young children with CP in both clinical practice and future research is now possible.

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Author contribution

JLW, KLB, RNB, and PSWD designed research, JLW conducted the research, PSWD and RNB provided essential materials, JLW analysed data and performed statistical analyses, JLW wrote the paper, and JLW, KLB, RNB and PSWD reviewed and approved the final content.

Conflict of interest

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