Clinical Nutrition 32 (2013) 579–584

Contents lists available at SciVerse ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

The use of bioelectrical impedance analysis to estimate total body water in young children with cerebral palsy☆

Kristie L. Bell [a,b,c,d,*], Roslyn N. Boyd [a,b], Jacqueline L. Walker [a,c], Richard D. Stevenson [e], Peter S.W. Davies [c]

[a] Queensland Cerebral Palsy and Rehabilitation Research Centre, School of Medicine, The University of Queensland, Australia
[b] Department of Paediatric Rehabilitation, Royal Children's Hospital, Brisbane, Queensland, Australia
[c] Children's Nutrition Research Centre, School of Medicine, The University of Queensland, Australia
[d] Queensland Children's Medical Research Institute, The University of Queensland, Australia
[e] Division of Developmental Pediatrics, University of Virginia (UVA) School of Medicine, and UVA Children's Hospital, USA

ARTICLE INFO

Article history:
Received 3 August 2012
Accepted 4 October 2012

Keywords:
Cerebral palsy
Children
Body composition
Bioelectrical impedance analysis

SUMMARY

Background & aims: Body composition assessment is an essential component of nutritional evaluation in children with cerebral palsy. This study aimed to validate bioelectrical impedance to estimate total body water in young children with cerebral palsy and determine best electrode placement in unilateral impairment.

Methods: 55 young children with cerebral palsy across all functional ability levels were included. Height/length was measured or estimated from knee height. Total body water was estimated using a Bodystat 1500MDD and three equations, and measured using the gold standard, deuterium dilution technique. Comparisons were made using Bland Altman analysis.

Results: For children with bilateral impairment, the Fjeld equation estimated total body water with the least bias (limits of agreement): 0.0 L (−1.4 L to 1.5 L); the Pencharz equation produced the greatest: 2.7 L (0.6 L–4.8 L). For children with unilateral impairment, differences between measured and estimated total body water were lowest on the unimpaired side using the Fjeld equation 0.1 L (−1.5 L to 1.6 L)) and greatest for the Pencharz equation.

Conclusions: The ability of bioelectrical impedance to estimate total body water depends on the equation chosen. The Fjeld equation was the most accurate for the group, however, individual results varied by up to 18%. A population specific equation was developed and may enhance the accuracy of estimates. Australian New Zealand Clinical Trials Registry (ANZCTR) number: ACTRN12611000616976.

1. Introduction

Poor nutrition and growth abnormalities are frequently reported in children with cerebral palsy (CP)[1,2] and have been linked with increased health care utilisation and reduced societal participation.[3] Despite its importance, the assessment of nutritional status in children with CP is not straightforward. Standard anthropometric measures of height and weight may be difficult to obtain in this population[4] and interpretation of these measures is complex.[5] In the clinical setting, weight for height indices, including the body mass index (BMI) are often used to estimate body size and as an indicator of body fatness in different populations.[6] Due to known alterations in growth and body composition in children with CP, assumptions regarding the relationship between weight for height indices and body fatness in typically developing children are not appropriate for use in this population.[5] A thorough clinical assessment of nutritional status in children with CP requires an accurate and reliable measure of body composition.[7]

The measurement of body composition in children with CP in the clinical setting is fraught with difficulty and there is little consensus in the literature regarding the best method to utilise.[5,8,9] Bioelectrical impedance analysis (BIA) is quick, non-invasive and lends itself to routine clinical use.[10] It is being used with increasing frequency in studies of children with CP.[9–15] BIA is based on electrical theory where the volume of a cylindrical conductor is proportional to its length^2/impedance.[16] In humans, this volume is

☆ This work was presented (in part) at the Australasian Academy of Cerebral Palsy and Developmental Medicine, Brisbane 2012, and the American Academy of Cerebral Palsy and Developmental Medicine, Toronto 2012.

* Corresponding author. Queensland Cerebral Palsy and Rehabilitation Research Centre, 7th Floor, Block 6, Royal Brisbane and Women's Hospital, Herston Rd, Herston, Queensland 4029, Australia. Tel.: +61 7 3636 5537; fax: +61 7 3636 5480.
E-mail address: k.bell@uq.edu.au (K.L. Bell).

0261-5614/$ – see front matter
http://dx.doi.org/10.1016/j.clnu.2012.10.005

equivalent to total body water (TBW). A number of equations to estimate TBW from measures of height (or length) and impedance have been developed in different populations.[9,17–21] Criterion validation studies in children with CP remain limited and have been small in size with limited scope.[9–11,13] BIA has been validated for use in five to 12 year old children with mild motor impairment (Gross Motor Function Classification System (GMFCS) I and II),[10] and two to 21 year old children and adolescents with more severe impairment (GMFCS III–V).[9,11,13] Results indicate the ability of BIA to estimate TBW in individuals with CP is dependent on the equation used.[10] Equations to estimate TBW in young children with CP across the full spectrum of motor impairment have not been investigated. Our previous work highlighted difficulties with the use of the four electrode technique in children with unilateral impairment where BIA consistently overestimated TBW by an average of 1.1 kg (limits of agreement −0.3 to 2.5 kg) when impedance was measured on the unimpaired side.[10] Optimal electrode placement in children with unilateral impairment requires further investigation. The reliability of impedance measures in children with CP has not been reported.

This study aimed to determine (a) the criterion validity of three different equations to estimate TBW from impedance in preschool children with CP across the full range of motor severity; (b) optimal electrode placement in preschool children with unilateral CP and (c) the reliability of impedance measurements in young children with CP.

2. Methods

2.1. Participants

Children born between 1st September 2006 and 31st December 2009 with CP across all GMFCS Levels were recruited for the study.[22] Participants were excluded if they had a progressive or neurodegenerative lesion or a chromosomal abnormality known to affect growth and not historically considered CP.[23]

This study was conducted as part of a larger longitudinal investigation into the growth and health outcomes of preschool aged children with CP (NHMRC569605) (Australian New Zealand Clinical Trials Registry (ANZCTR) number: ACTRN12611000616976).[22] Recruitment for this study commenced in April 2009. Suitable candidates were recruited through the Queensland Children's Health Services District, the Queensland CP Health Service, the Queensland CP Register, the Queensland CP League, and other regional hospitals and health service districts throughout Queensland.

Written, informed consent was obtained from the parents or legal guardians. Ethical approvals were received from The University of Queensland Medical Research Ethics Committee (2008002260), the Children's Health Services District Ethics Committee (HREC08/QRCH/112/AM01), the CP League of Queensland (CPLQ 2008/2010 1029), 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), Central Queensland Human Research Ethics Committee (SSA/10/QCQ/13), and the Mater Health Services Human Research Ethics Committee (1520EC). Children and parents/guardians attended their closest centre or outreach hub location for appointments. The same study team visited the nine geographic locations to collect data.

2.2. Methods

Functional severity was determined for each child using the internationally accepted GMFCS.[24] Type of CP (eg, spastic, dystonic, or hypotonic) and motor distribution (unilateral, bilateral, number of limbs involved) was assessed according to the criteria of Sanger[25] and the internationally accepted classification system on the European CP Register.[26] All motor assessments were conducted by two trained, independent physiotherapists. When initial consensus on classification was not reached, agreement was reached through case discussion.

Weight was measured to the nearest 100 g using chair scales (Seca Ltd, Germany) or portable electronic scales (Homemaker Ltd, Australia). Height or length (for children under two years of age or children unable to stand) was measured to the last completed millimetre with a portable stadiometer/length measuring board (Shorr Productions, LLC, Maryland, USA). Knee height was measured with an anthropometer and the left hand side of the body or the least impaired side for children with unilateral impairment (Holtain Ltd, Dyfed, UK). For children where a measure of height or length was not possible, height was estimated from knee height using population specific published validated equations.[4]

Impedance (Ohm) was measured using a Body Stat 1500MDD (Isle of Mann, UK) at 800 μA and a fixed frequency of 50 kHz. Children were required to lie in a supine position with arms and legs slightly abducted from the trunk. All jewellery and metallic objects were removed prior to measurement. The electrical current was applied through two non-polarising surface electrodes placed at the dorsal surfaces of the hand and foot over the distal aspect of the second and third metacarpals and metatarsals. The voltage drop was measured by two further electrodes placed at the right pisiform prominence of the wrist and between the lateral and medial malleoli of the ankle. The proximal and distal electrodes were placed a minimum of 5 cm apart. All measurements were conducted on both sides of the body in duplicate, with a third measurement taken if the difference between the first two measurements was greater than 5 Ω. The mean of the two closest values was used for analysis.

TBW was measured non-invasively, using the deuterium-dilution technique.[27] Children were given a dose of deuterium in the form of water either orally or via feeding tube. Any spillage was collected in an absorbent cloth which was weighed before and after dosing to accurately determine how much fluid was lost.[28] A single baseline urine sample was collected prior to administration of the dose to determine natural baseline enrichments of the isotopes and a second urine sample was collected at approximately five hours after dosing to enable calculation of the body water pool using standard equations.[27] Collection of urine samples from children with poor or no bladder control involved the use of urine bags or the inclusion of an absorbent liner in their diaper from which urine was extracted for analysis.[28]

2.3. Data analysis

Age corrected for gestational age was used for those children under two years of chronological age who were born prior to 37 weeks gestation. Chronological age was used for all other children.

TBW was estimated from impedance using three previously published equations.[17,18,20] These equations were selected as they were all developed in groups containing children of preschool age and are all based on electrical theory.

Kushner equation[18]: $TBW = 0.04 + 0.593\ (\text{height (m)}^2/\text{Impedance}) + 0.065\ \text{weight (kg)}$

Pencharz equation[17]: $TBW = 2.99 + 0.649\ (\text{height (m)}^2/\text{Impedance})$

Fjeld equation[20]: $TBW = 0.76 + 0.180\ (\text{height (m)}^2/\text{Impedance}) + 0.390\ \text{weight (kg)}$

For children with unilateral impairment, differences between TBW estimated from impedance on the impaired and unimpaired