


BODY COMPOSITION

Practical measurement of body composition using bioelectrical impedance, air displacement plethysmography and ultrasound in stable outpatients with short bowel syndrome receiving home parenteral nutrition: comparison of agreement between the methods

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Keywords

air displacement plethysmography, bioelectrical impedance analysis, body composition, home parenteral nutrition, short bowel syndrome.

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How to cite this article

Jones D. J., Lal S., Gittins M., Strauss B. J. G., Burden S. T. (2019) Practical measurement of body composition using bioelectrical impedance, air displacement plethysmography and ultrasound in stable outpatients with short bowel syndrome receiving home parenteral nutrition: comparison of agreement between the methods. *J Hum Nutr Diet.* **32**, 288–294
<https://doi.org/10.1111/jhn.12613>

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Introduction

Chronic intestinal failure (IF) as a result of short bowel syndrome (SBS) requires artificial nutritional venous supplementation, known as home parenteral nutrition (HPN) ⁽¹⁾,

and many people require this indefinitely ^(2,3). Nutritional status can indicate whether or not an individual is at risk of diminished physical and mental function as a result of weight loss, malnutrition, nutrient deficiencies, sarcopenia and cachexia ⁽⁴⁾. Standard measures of nutritional status

Abstract

Background: People diagnosed with intestinal failure (IF) as a result of short bowel syndrome are dependent on home parenteral nutrition (HPN). Measuring nutritional status is essential for monitoring treatment.

The present study aimed to determine the agreement and feasibility of three methods bioelectrical impedance analysis (BIA), ultrasound and air displacement plethysmography (ADP) for measuring body composition in people receiving HPN.

Methods: Body composition data were collected from patients attending an IF clinic.

Results: There were 50 participants recruited and data were collected for BIA ($n = 46$), ultrasound ($n = 49$) and ADP ($n = 9$). Numbers for ADP were much lower because of a lack of participant uptake. Fat-free mass (FFM) measured by BIA and ultrasound in comparison to ADP was found to have good intraclass correlation (ICC) 0.791 (95% confidence interval (CI) CI -0.21 to 0.96) and a moderate ICC 0.659 [95% (CI) -0.27 to 0.92], respectively. Fat mass (FM) measured by both BIA and ultrasound in comparison to ADP was found to have moderate ICC 0.660 (95% CI -0.28 to 0.92) and poor ICC -0.005 (95% CI -0.73 to 0.65), respectively.

Conclusions: Compared to ADP, BIA indicated moderate to good agreement for measuring body composition, whereas ultrasound indicated far less agreement, particularly when measuring FM. The lack of uptake of ADP suggests that participants found the Bodpod (COSMED Srl, Shepperton, UK) unfavourable. Considering that ultrasound has limited agreement and ADP was not the preferred option for participants, BIA shows some potential. However, the difference between ADP and BIA was larger for FM compared to FFM, which needs to be considered in the clinical setting.

include weight, body mass index (BMI) and anthropometry; however, it is apparent that simply relying on these measures can miss clinically important information regarding body composition⁽⁵⁾. More accurate and novel techniques for measuring body composition are readily available, including computed tomography (CT), air displacement plethysmography (ADP), ultrasound and bioelectrical impedance analysis (BIA). However, there are minimal data on the usefulness of these measurements in people requiring HPN. In addition, assessment of body composition in these patients is difficult, particularly when measuring changes in fat mass (FM) and fat-free mass (FFM), which are useful indicators of sarcopenia, malnutrition and dehydration⁽⁶⁾. Primarily body composition disturbances in people with IF are related to FFM and, although losses from different components of lean tissue have not been well described, FFM index has been identified as an independent risk factor for mortality⁽⁷⁾.

The present study aimed to assess the agreement and practicality of three methods (BIA, ultrasound and ADP) for measuring body composition in chronic IF outpatients with SBS, who were dependent on HPN.

Materials and methods

This was a comparison study aiming to determine agreement between three techniques to measure body composition. Data were collected from participants attending an IF clinic. Measurements of body composition undertaken were ultrasound and BIA. From the IF clinic, 94 participants were invited to attend a session, at a different time and location, for measurement of ADP⁽⁸⁾.

Inclusion criteria

Inclusion criteria comprised participants attending Salford Royal IF clinics who had been in receipt of HPN for ≥ 3 months, were aged ≥ 18 years, had a primary diagnosis of SBS-IF defined by ESPEN guidelines⁽¹⁾ and were assessed as clinically stable (aprexial and metabolically stable).

Exclusion criteria

Exclusion criteria comprised being unable to give informed consent, being pregnant, being unable to stand or difficulty with mobility, pyrexial or unstable biochemistry or unstable haematology, and having a pacemaker or metallic implant.

Recruitment

Research Nurses recruited participants and a trained nutrition researcher collected BIA and ultrasound body composition data. Participants were invited to be measured by ADP at a facility 6 miles away from the location.

Data collection

All measurements were collected from each participant on the same day apart from ADP, which was collected as soon as possible, on a different day. All data were collected when the participants were away from home and between HPN infusions. Participants were fasted for at least 2 h as a result of attending a clinic or were instructed to do so prior to attending ADP.

Height was measured (to the nearest 1 cm) using a portable stadiometer (Harpender Pocket Stadiometer; Practical Metrology, Lancing, UK). Weight (to the nearest 0.1 kg) and BIA were measured using medically approved scales (foot to foot single frequency; Tanita BC-420; Tanita Europe Ltd, Manchester, UK). Handgrip was measured with the nondominant hand using Takei 5001 Grip Dynamometer Analogue (Takei Scientific Instruments Co. Ltd, Niigata, Japan). The BodyMetrix machine (IntelaMetrix, Brentwood, CA, USA) was used to measure body composition by ultrasound (<http://www.intelamatrix.com/intlBX2000>) and the Bodpod machine (COSMED Srl, Shepperton, UK) was used to measure body composition by ADP. Standard operating procedures were followed for all measurements (Appendix S1). All three techniques used a two compartmental model. One technique (BIA) measures a component of FFM, calculates FFM and secondarily derives FM, whereas the other two techniques (ADP and ultrasound) measure a different component of FM each, calculate FM and secondarily derive FFM⁽⁹⁾. Sarcopenia is characterised by the loss of muscle mass and strength⁽⁴⁾ and published cut-off points for low FFM were used⁽¹⁰⁾. Sarcopenia was determined by identifying those who had low handgrip strength⁽¹¹⁾ and low FFM. Handgrip strength was also calculated as a percentage of normative median values, accounting for age and gender⁽¹²⁾.

Sample size

We planned to recruit 50 people to undergo all measurements for this comparison study. This sample size calculation was based on 260 patients receiving HPN at this site and previous literature indicating that 50–60% of HPN registrants will have a primary diagnosis of SBS⁽¹³⁾. Therefore, it was estimated that 130–156 patients would have SBS and be eligible for the study. Assuming a 45% response rate and 80% confidence intervals (CI), a sample size of approximately 64 (59–70) patients was expected.

Ethical approval

Ethical approval was obtained from Research Ethics Committee (16/SW/0146). Procedures were followed in accordance with the ethical standards of the regional

committee on human experimentation and approval was obtained from the relevant committee on human subjects.

Statistical analysis

Data collected from study participants were summarised using descriptive statistics. To assess agreement between measurement techniques BIA, ultrasound and ADP for assessing body composition, an intraclass correlation coefficient (ICC) with corresponding 95% CI were calculated. Calculations were carried out in SPSS, version 23 (IBM Corp., Armonk, NY, USA). ICC was conducted using specific body composition measurements. Data were analysed using a mean of k measurements ($k = 2$), absolute agreement and a two-way mixed effects model. Agreement was assessed as: less than 0.5 was poor, between 0.5 and 0.75 was moderate, between 0.75 and 0.9 was good, and values greater than 0.90 were excellent.

Results

From the eligible patients who were invited to participate, 58 completed reply slips. Of these, 50 attended a data

collection session and nine attended an ADP session (see Supporting information, Fig. S1).

Of the participants who completed one or more assessment techniques for body composition ($n = 50$), 68% were female, 90% were white British and all had an underlying diagnosis of SBS-IF. Table 1 summarises the participant characteristics. Reasons for HPN were: Crohn's disease in 25 (53.2%), surgical complications in 11 (23.4%), mesenteric ischaemia in six (12.8%), radiation enteritis in two (4.3%), cancer in one (2.1%) and polyposis in one (2.1%); missing data ($n = 4$). Any missing data were with respect to time, frequency and diagnosis from gaps in self-reported data, and one participant was in a wheelchair such that height and weight were not recorded. Table 2 summarises FM and FFM obtained from each measurement technique.

The incidence of low FFM and sarcopenia in people receiving HPN as a result of SBS-IF is shown in Table 3. However, these data did not facilitate further evaluation using sensitivity and specificity because of low sample size and either no incidence or low incidence of sarcopenia and FFM.

Comparison of BIA with ADP for measuring FFM was found to have a good ICC score of 0.791 (95%

Table 1 Characteristics of the total sample and the air displacement plethysmography (ADP) subset

	Males Mean (SD) $n = 16$	Females Mean (SD) $n = 34$	Total Mean (SD) $n = 50$
Data from total sample			
Age (years)	53.06 (13.54)	58.88 (9.69)	57.02 (11.27)
Time on HPN (months) (missing: 4)	107.67 (92.08)	104.10 (92.02)	105.26 (91.02)
Frequency HPN per week (missing: 3)	5.13 (1.69)	5.94 (1.44)	5.68 (1.55)
Height (m)	1.75 (0.06)	1.59 (0.08)	1.64 (0.12)
Weight (kg) (missing: 1)	78.45 (8.99)	61.32 (14.67)	66.91 (15.32)
BMI (kg m^{-2}) (missing: 1)	25.48 (2.34)	24.23 (5.54)	24.64 (4.75)
Handgrip strength (kgf)	33.06 (7.52)	16.28 (4.15)	21.65 (9.56)
Handgrip (% of normative data)*	71.47 (15.97)	59.75 (14.71)	63.50 (15.95)
	Males Mean (SD) $n = 5$	Females Mean (SD) $n = 4$	Total Mean (SD) $n = 9$
Data from ADP subset			
Age (years)	44.80 (13.95)	60.75 (12.50)	51.89 (15.05)
Time on HPN (months)	71.40 (64.53)	100.75 (101.97)	84.44 (78.87)
Frequency HPN per week	4.40 (1.67)	6.75 (0.50)	5.44 (1.74)
Height (m)	1.77 (0.81)	1.63 (0.03)	1.71 (0.10)
Weight (kg)	84.66 (10.70)	70.65 (14.62)	78.43 (13.85)
BMI (kg m^{-2})	26.90 (2.22)	26.60 (5.47)	26.77 (3.70)
Handgrip Strength (kgf)	37.73 (5.66)	19.46 (4.56)	29.61 (10.80)
Handgrip (% of normative data)*	77.91 (13.46)	73.06 (9.56)	75.75 (11.46)

BMI, body mass index; HPN, home parenteral nutrition; kgf, kg force; PNIQ, parenteral nutrition impact questionnaire.

*Definition from Dodds *et al.* (12).

Table 2 Body fat mass and fat-free mass recorded by bioelectrical impedance analysis, ultrasound and air displacement plethysmograph

	Males (N = 16)		Females (N = 34)		Total (N = 50)	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
Total sample						
BIA FM (kg)	15	16.57 (4.69)	31	16.65 (11.83)	46	16.62 (10.01)
Ultrasound FM (kg)	16	23.04 (4.50)	33	20.74 (8.08)	49	21.49 (7.15)
ADP FM (kg)	5	28.38 (7.13)	4	28.83 (10.56)	9	28.58 (8.20)
ADP subset						
BIA FM (kg)	5	19.96 (3.47)	4	21.90 (12.82)	9	20.82 (8.29)
Ultrasound FM (kg)	5	21.88 (3.42)	4	15.65 (5.12)	9	19.11 (5.15)
Total sample						
BIA FFM (kg)	15	62.39 (6.86)	31	43.03 (8.89)	46	49.34 (12.31)
Ultrasound FFM (kg)	16	55.40 (9.90)	33	41.04 (11.09)	49	45.73 (12.61)
ADP FFM (kg)	5	55.20 (7.05)	4	41.62 (5.45)	9	49.17 (9.34)
ADP subset						
BIA FFM (kg)	5	64.70 (9.91)	4	48.75 (8.10)	9	57.61 (12.01)
Ultrasound FFM (kg)	5	62.78 (9.27)	4	54.97 (15.56)	9	59.31 (12.28)

ADP, air displacement plethysmograph; BIA, bioelectrical impedance analysis; FM, fat mass; FFM, fat-free mass.

Table 3 Participants identified as having low fat-free mass and sarcopenia measured by air displacement plethysmography, bioelectrical impedance analysis, and ultrasound

	Low fat-free mass* n (%)	Sarcopenic† n (%)
Total sample		
BIA (n = 46)	9 (18)	2 (4)
US (n = 49)	22 (44)	6 (12)
ADP subset		
ADP (n = 9)	4 (50)	0 (0)
BIA (n = 9)	1 (11)	0 (0)
US (n = 9)	1 (11)	0 (0)

ADP, air displacement plethysmograph; BIA, bioelectrical impedance analysis; US, Ultrasound;

*Definition from Schutz *et al.* (10).

†Definition from Cederholm *et al.* (4).

CI -0.21 to 0.96) and, for measuring FM, was found to have a moderate ICC score of 0.660 (95% CI -0.28 to 0.92). Comparison of ultrasound with ADP for measuring FFM was found to have a moderate ICC score of 0.659 (95% CI -0.27 to 0.92) and, for measuring FM, was found to have a poor ICC score of -0.005 (95% CI -0.73 to 0.65) (Fig. 1). A comparison of US and BIA is provided in the Supporting information (Fig. S2).

Discussion

The results of the present study suggest that, in patients with SBS-IF who require HPN, it is practical to undertake BIA and ultrasound ($n = 50$) in an outpatients setting. Although wide 95% CI on all ICC were present as a result

of the small available sample size ($n = 9$), BIA had good agreement with ADP when measuring body composition, which is in accordance with previous data measuring percentage fat in 41 healthy participants using ADP and BIA with good agreement (14). However, caution is warranted because the different measurement techniques use different models and so there is likely to be a propagation of error from the measured component through to the last derived component (9). Also, BIA has previously shown variability in clinical populations and a lack of precision in longitudinal studies (15). BIA is also susceptible to error as a result of variations in internal fluid balances (16). ADP was the criterion measurement but, because of a lack of availability, it is not practical for routine outpatient assessments.

In comparison to BIA, ultrasound demonstrated far less agreement, particularly when measuring FM. A review of body composition using imaging techniques concluded that, even though the results from ultrasound scanning were promising, the accuracy of derived estimates of adiposity still needed to be examined against appropriate reference methods (15). It has also been demonstrated, in 47 healthy, young overweight/obese adults, that ultrasound predictions of body fat were significantly lower than fat percentage predicted by ADP (17). This is possibly a result of the similar acoustic impedance of fat and muscle and the visual border between fat and muscle being less distinct than that between muscle and bone (18). In addition, the use of a body-matrix ultrasound unit on a group of 60 overweight and normal Brazilian military reported weak correlations between skinfolds and ultrasound at the majority of anatomical locations tested (18). It is suggested that training, experience and further automation of

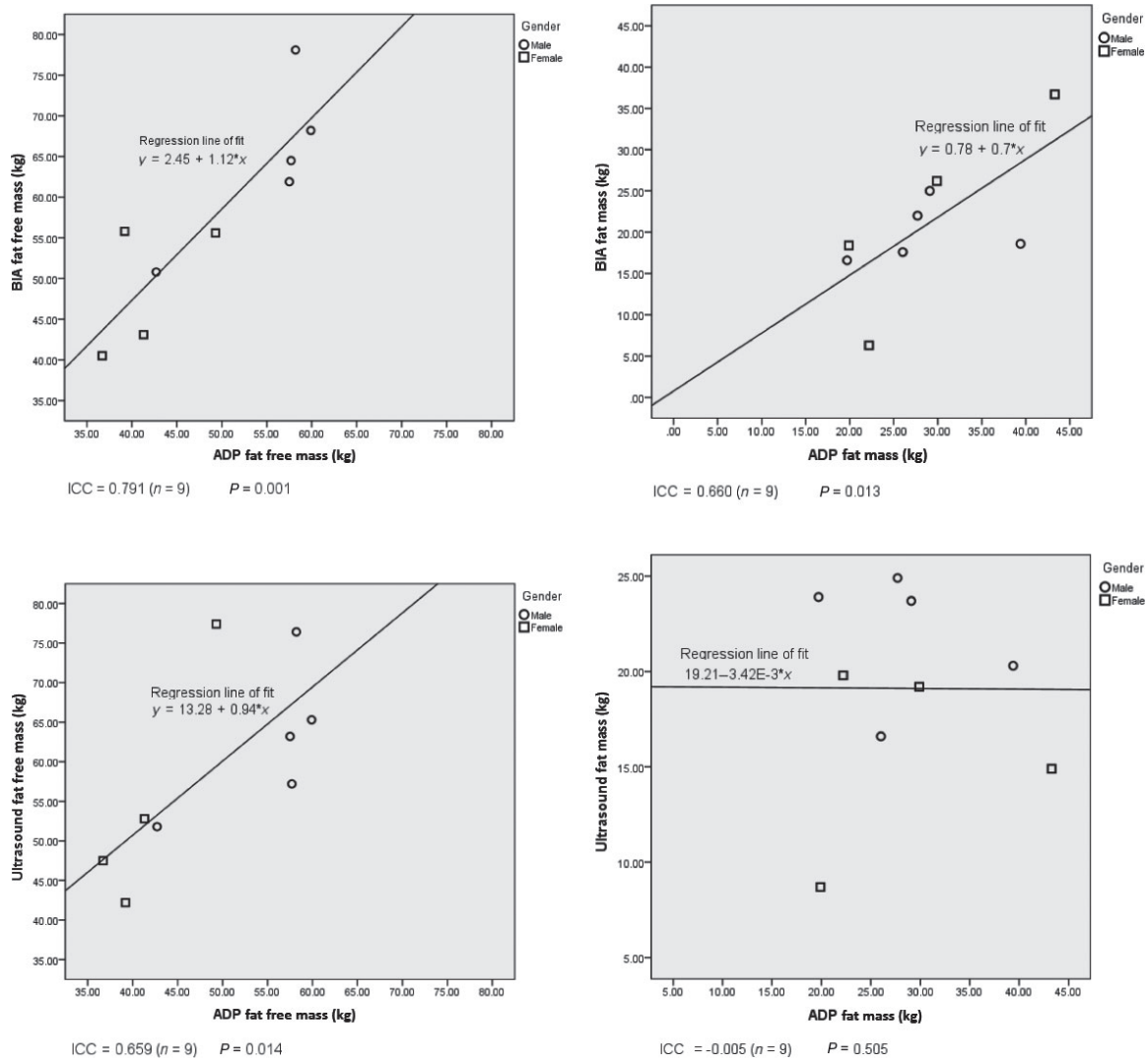


Figure 1 Scatter plots for the comparison of bioelectrical impedance analysis and ultrasound to air displacement plethysmography in both fat-free mass and fat mass in the air displacement plethysmography (ADP) subset. ICC, intraclass correlation coefficient; BIA, bioelectrical impedance analysis.

measurements in ultrasound scanning could address some of these issues ^(19,20).

The results from the present study require further investigation because of the low sample size for ADP. In addition, previous work suggests that ADP measurements may deviate from the reference standard measure of dual energy X-ray absorptiometry (DEXA) ⁽²¹⁾, particularly in populations with a low BMI ⁽²²⁾.

Assessment of FFM and FM by CT was not possible within this study population as a result of the chronic nature of the disease and therefore a lack of routine occurrence of CT scans.

Uptake with ADP was considerably lower than both BIA and ultrasound. Also, those who participated in ADP were not identified as having sarcopenia and participants

were generally better nourished, with a lower mean age (51.89 years compared to 57.02 years, $P < 0.001$) and a higher mean grip strength (29.61 kgf compared to 21.65 kgf, $P < 0.001$) compared to the total sample.

The nature of ADP means that participants have to change into swimwear, remove all jewellery and glasses, and sit inside an enclosed capsule, operated by magnetic locks, for up to 60s. The ADP machines are also very expensive pieces of equipment and so have limited accessibility. The use of ultrasound and BIA may appear more favourable to patients rather than ADP because of their restricted time and mobility during HPN infusions; negative body image; self-consciousness as a result of the presence of a stoma ⁽²³⁾; and feeling more vulnerable because of the nature of their condition and dependency on HPN.

Therefore, future work may rule out the use of ADP in this population and determine the validity of BIA and ultrasound against the reference standard DEXA^(24–26).

Conclusions

Within this sample of the SBS population, ultrasound appears to have a limited applicability as a result of low validity when measuring FM; CT scans are not routinely performed at regular intervals in chronic disease management; and ADP was unfavourable to participants. The use of BIA shows some potential in patients with SBS-IF as a result of the moderate to good ICC scores when comparing BIA and ADP. However, the difference between mean data for FM and FFM is too great to be of any use clinically, without further work employing a larger sample size. Improvements in validity for body composition measurements may be gained with the use of multifrequency BIA or automated ultrasound⁽²⁵⁾. Moreover, digital anthropometry with three-dimensional photonics may provide a way forward if used in conjunction with BIA or ultrasound⁽²⁶⁾.

Transparency declaration

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

Conflict of interests, source of funding and authorship

The authors declare that they have no conflicts of interest. This work was supported by an unrestricted research grant from Shire International GmbH and supported by the NIHR Manchester Clinical Research Facility. The views expressed are those of the author(s) and not necessarily those of Shire International, the NHS, the NIHR or the Department of Health.

DJ acquired, analysed and interpreted the data, as well as drafted the full paper and revised after co-author feedback. MG provided support for the statistical analysis and the write-up, and contributed to the drafting and revision of the paper. SL contributed to the conception of the design of the study, and aided in the drafting and revising of the paper. SB established the conception and design of the study and aided in data interpretation, and also contributed to the drafting and revision of the manuscript. All authors approved the final version of the paper submitted for publication.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Standard operating procedures for data collection.

Figure S1. Flow chart of participation and data collection.

Figure S2. Scatter plots for the comparison of bioelectrical impedance analysis and ultrasound.