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Assessment of Body Composition in Peritoneal Dialysis Patients Using Bioelectrical Impedance and Dual-Energy X-Ray Absorptiometry

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Key Words

Dual-energy X-ray absorptiometry · Multifrequency bioimpedance · Segmental body composition · Peritoneal dialysis · Nutrition · Fat · Muscle

Abstract

Introduction: Protein energy wasting is closely related to increased morbidity and mortality in peritoneal dialysis (PD) patients. Simple reliable and easily available methods of determining nutritional status and recognition of short-term changes in body composition are therefore important for clinical practice. ***Methods:*** We compared whole-body and segmental composition using multifrequency bioelectrical impedance analysis (MF-BIA) and dual-energy X-ray absorptiometry (DEXA) in 104 stable PD patients. ***Results:*** Assessment of whole-body composition showed that lean body mass (LBM) was highly correlated with good method agreement using DEXA as the reference test ($r = 0.95$, $p < 0.0001$; bias –0.88 kg, 95% CI –1.53 to 0.23 kg). Similarly, high correlation and good method agreement were found for fat mass ($r = 0.93$, $p < 0.0001$; bias 0.69 kg, 95% CI 0.03–1.36 kg). Segmental analysis of LBM revealed strong correlations between LBM for trunk, left and right arms and legs ($r = 0.90$, 0.84, 0.86, 0.89 and 0.90, respectively, $p < 0.0001$). Bone mineral content derived by MF-BIA overestimated that measured by DEXA (bias 0.740 kg, 95% CI 0.66–0.82 kg). ***Conclusion:*** MF-BIA may potentially be a useful tool for determining nutritional status in PD patients and serial estimations may help recognize short-term changes in body composition.

Introduction

Protein energy wasting is very common in patients with advanced kidney failure and those on dialysis [1]. The increased risk of mortality associated with protein energy wasting is often confounded by the association between increasing co-morbidity, both physical and psychological, and poor nutrition [2]. As there is currently no gold standard measurement for determining protein energy wasting, the K/DOQI guidelines recommended a combination of methods and assessments [1], including serum albumin measurement, calculation of creatinine generation rate [3], dietary diaries and interviews, subjective global assessment (SGA), anthropometric assessment [4], comparison with an estimation of ideal body weight, dual-energy X-ray absorptiometry (DEXA) scanning and bioimpedance. However, many of the simpler methods are prone to error, due to a combination of measurement and observer error or bias, or patient recall [5], and the difficulty in assessing body composition [6], as

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the equations used to estimate body water and fat-free mass (FFM) were typically developed from historic healthy cohorts [7, 8]. Although the selective global assessment has been reported to have a high predictive value for mortality in peritoneal dialysis patients [9], it consumes time and is a subjective evaluation, which may therefore reduce its reproducibility, particularly over time with different adjudicators.

However, it is important to detect protein energy wasting, and this may be difficult in a busy clinical practice as loss of lean body mass (LBM) or fat weight may not be readily apparent due to increased fluid retention. Body composition analysis using bioimpedance and DEXA techniques are becoming more readily available [10], and some clinical guideline committees have suggested that DEXA, which can estimate bone mineral, fat and LBM directly, is the most reliable method [11]. However, bioimpedance has developed over time from single-frequency to the current multifrequency machines, and from 4- to 8-point contact electrodes which allow assessment of segmental body composition [12, 13].

Multifrequency bioelectrical impedance analysis (MF-BIA) with segmental body analysis also provides an estimate of body composition. The aim of this study was to evaluate MF-BIA in assessing body composition compared to standard DEXA scanning.

Material and Methods

Patient Selection

Patients attending the Royal Free Hospital peritoneal dialysis centre routinely have DEXA scanning performed on an annual basis as part of their ongoing clinical care. MF-BIA is performed on patients attending the centre as part of their dry weight assessment. Patients with implantable defibrillators, cardiac pacemakers and amputees were excluded from the study. Patients who had peritonitis or hospital admissions within 3 months prior to measurements were excluded from the study, as was any patient who had an intercurrent event between measurements.

Ethical approval was granted by the local ethical committee as audit and clinical service development.

Methods

For both DEXA and MF-BIA assessments, peritoneal dialysis fluid was drained from the abdomen prior to measurement [14]. DEXA scanning was performed in the supine position with patients wearing a hospital gown, using the Hologic QDR Discovery W (S/N47096) model (Hologic, www.hologic.com). The radiation exposure is estimated to be one tenth of that for a standard chest X-ray. Whole-body composition including total and segmental lean, total body fat mass (FM) and bone mineral content (BMC) was calculated with the QDR system software for Windows XP Version 12.5 (Hologic, www.hologic.com).

Table 1. Patient demographics (n = 104)

Characteristic	Mean ± SD	Range
Age, years	57.1 ± 17	22–86
Height, cm	163.2 ± 11.3	133–185
Weight, kg	67.5 ± 15.8	35.1–111
Body mass index	25.3 ± 4.9	16.2–36.7
Body surface area, m^2	1.9 ± 0.3	1.1–2.5
Vintage of dialysis, years	6.2 ± 8.3	0.1–16.9

For bioelectrical impedance measurements, the InBody 720 Body Composition Analysis (Biospace, www.biospace.com) was used. The direct segmental MF-BIA analysis method was employed using the tetrapolar 8-point tactile electrode system, with 30 impedance measurements taken by using 6 frequencies (1, 5, 50, 250, 500, 1,000 kHz) at each of 5 segments (right arm, left arm, trunk, right leg and left leg), and reactance by 15 impedance measurements using 3 frequencies (5, 50, 250 kHz) at each of the 5 segments, which allows determination of body water [15] and the assessment of segmental body composition [12, 16]. Height was measured by a standard wall-mounted measure (Sigmeas 1, Doherty Signature Range, www.mediclick.co.uk).

FM, LBM and BMC were obtained with DEXA. To allow comparison with MF-BIA, we defined FFM as LBM + BMC as measured by DEXA. For MF-BIA, FFM was defined as the sum of soft lean mass and mineral (osseous) content, and soft lean mass as the sum of total body water, protein and mineral (non-osseous) content. To equate the terms used for body composition by the two different methods, we used the term 'lean body mass' (DEXA) as equivalent to 'soft lean mass' (MF-BIA) and 'bone mineral content' (DEXA) as equivalent to 'mineral (osseous)' content (MF-BIA).

In MF-BIA total mineral content, both osseous and non-osseous content are estimated from the soft lean mass according to software supplied by the manufacturer (Biospace, www.biospace.com).

Statistical Analysis

Results are expressed as mean ± SD (Analyse-it Software 2009, Leeds, UK). Correlation analysis was performed to determine the strength of a relationship between the two methods, and Bland-Altman plots [17] were used to visually assess method agreement and bias between the two different methods. Statistical significance was taken at or below the 5% level.

Results

104 stable chronic peritoneal dialysis patients were studied (table 1), mean age 57 years, 54 women (52%), 30 patients (29%) had type 2 diabetes mellitus. 57 patients were Caucasoid (55%), 23 from the South Asian subcontinent (22%), 11 African/Afro-Caribbean (10.6%), 8 Ori-

Table 2. Patient whole-body and segmental composition measured by DEXA and MF-BIA in 104 stable peritoneal dialysis patients

	DEXA (mean ± SD)	MF-BIA (mean ± SD)
Body weight, kg	69.4 ± 15.0	70.0 ± 15.0
Fat-free mass, kg	47.6 ± 11.0	47.5 ± 11.6
Fat mass, kg	21.8 ± 8.2	22.5 ± 9.4
% body weight	31.0 ± 8.5	31.7 ± 10.3
Total lean body mass, kg	45.5 ± 10.6	44.7 ± 11.0
Lean trunk, kg	24.0 ± 5.5	21.1 ± 4.9
Lean left arm, kg	2.3 ± 0.8	2.5 ± 0.8
Lean right arm, kg	2.6 ± 0.8	2.5 ± 0.8
Lean left leg, kg	6.4 ± 1.8	7.2 ± 2.0
Lean right leg, kg	6.6 ± 1.9	7.2 ± 2.0
Bone mineral content, kg	2.1 ± 0.5	2.8 ± 0.8

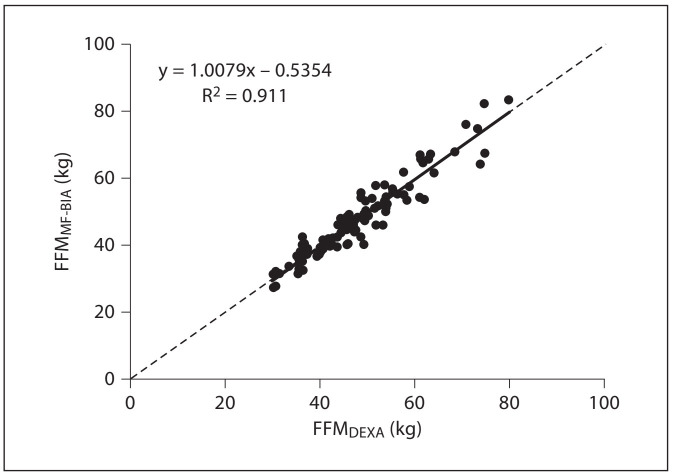

Fig. 1. Plot of total body FFM by DEXA and by MF-BIA. – – – = Identity line, —— = trendline.

Table 3. Correlation of body composition measurements DEXA vs. MF-BIA (r = correlation coefficient)

	r	95% CI	p
Fat-free mass	0.95	0.93–0.97	<0.0001
Fat mass	0.93	0.90–0.96	<0.0001
Total lean body mass	0.95	0.93–0.97	<0.0001
Lean trunk	0.90	0.86–0.93	<0.0001
Lean left arm	0.86	0.80–0.90	<0.0001
Lean right arm	0.84	0.77–0.89	<0.0001
Lean left leg	0.89	0.83–0.92	<0.0001
Lean right leg	0.90	0.85–0.93	<0.0001
Bone mineral content	0.77	0.68–0.84	<0.0001

ental and 4 from other ethnicities. All patients achieved the UK Renal Association clinical guideline weekly minimum Kt/V and creatinine clearance targets [18], and the prevalent peritonitis rate 0.03 episodes/patient treatment year. The mean daily urine output was 918 ± 707 ml, and median weekly urinary Kt/V 0.8 (0.2–1.3). The median time difference between DEXA and MF-BIA was 2 months (0–3), and mean weight difference 0.5 ± 0.18 kg. There was no correlation between weight difference and time interval between assessments (r = 0.11, p = 0.25).

Body weight and both FM and FFM as measured by DEXA and MF-BIA were similar (table 2; fig. 1). Moreover, there were significant correlations between the two methods, for both total body and segmental composition assessments (table 3). To compare the techniques, Bland-Altman analysis was performed (table 4), and there was minimal bias (–0.160 kg) for total body FFM. Similarly, there was good agreement, with minimal bias on segmental lean body composition for the arms (fig. 1) and legs (fig. 2). There was a greater variability in lean mass assessments for the legs compared to the arms (fig. 2, 3), and MF-BIA underestimated lean mass in the trunk compared to DEXA (table 4).

Although there was good correlation for assessment of total BMC (table 3), there was a significant bias, with MF-BIA reporting higher values than DEXA (fig. 4).

Discussion

Protein energy wasting is commonly encountered in peritoneal dialysis patients, and associated with increased morbidity and mortality [2, 19]. As such, reliable assessment of nutritional status is an important tool in routine clinical practice. Current techniques include SGA, anthropometric measurements, creatinine kinetics [3], DEXA and bioimpedance [10]. Previous reports have suggested that DEXA scanning is more accurate than SGA, anthropometric measurements and creatinine kinetics, particularly in assessing FM [20]. However, for everyday routine clinical practice the choice of a method to detect protein energy wasting by assessing body composition depends upon the balance between practicality, validity and cost. Whole-body DEXA scanning is not read-

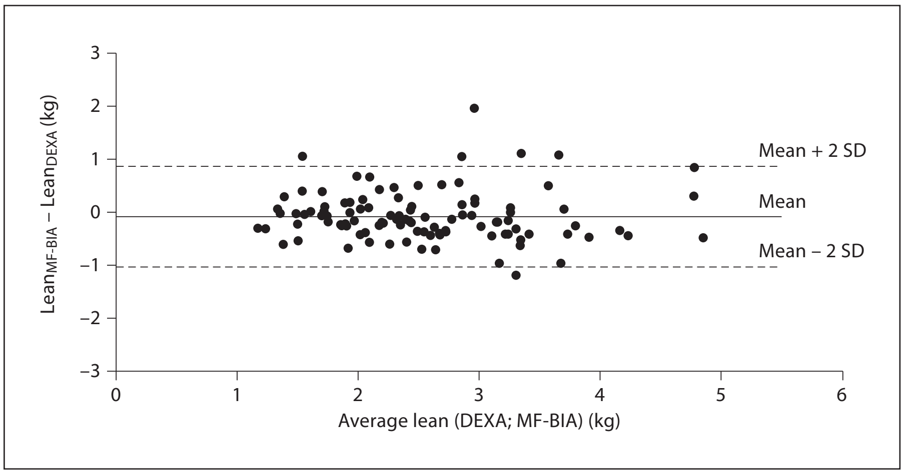

Fig. 2. Bland-Altman plot showing limits of agreement between segmental lean right arm assessed by DEXA and by MF-BIA.

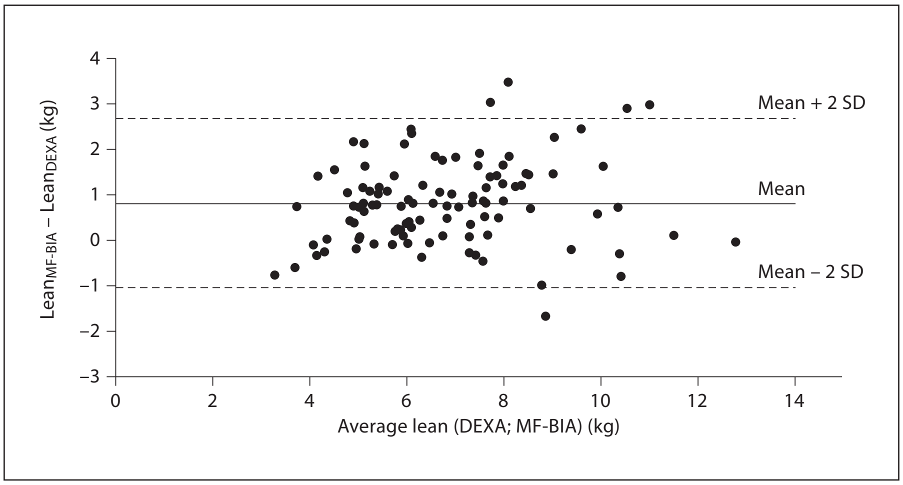

Fig. 3. Bland-Altman plot showing limits of agreement between segmental lean left leg assessed by DEXA and by MF-BIA.

ily available in peritoneal dialysis units, as equipment is typically located in radiology or nuclear medicine departments, whereas bioimpedance equipment can be portable.

Body composition in peritoneal dialysis patients varies with age, sex, ethnicity, diabetes, and dialysis vintage [13, 21]. Although this was a single-centre study, our patient group was very heterogenous with a wide age distribution, 22–86 years, body weight 35–111 kg, body mass index 16–37, and also peritoneal dialysis vintage from 0.1 to 16.9 years. There was similar sex distribution, just under 30% were diabetic, and 45% of the study group came from the ethnic minorities. Despite such a heterogenous study population, there was a highly significant correlation and good method agreement for both total body and also compartmental composition between both methods. There have been very few previous studies which have

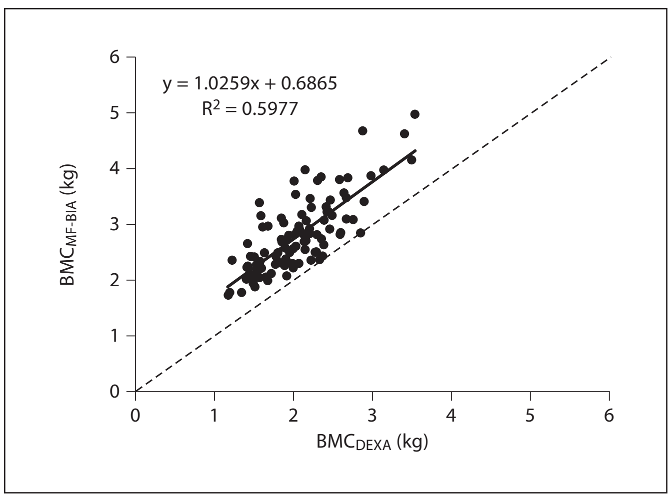

Fig. 4. Regression plot of BMC measured by DEXA and by MF-BIA. – – – = Identity line, —— = trendline.

Table 4. Comparison of body composition measurements by DEXA and MF-BIA using Bland-Altman analysis

	Bland-Altman (MF-BIA – DEXA), kg				
	bias	95% CI	SE	95% limits of agreement	
				lower	upper
Fat-free mass	–0.16	–0.84 to 0.51	0.340	–6.96	6.64
Fat mass	0.69	0.03 to 1.36	0.335	–6.00	7.39
Total lean body mass	–0.88	–1.53 to 0.23	0.328	–7.43	5.67
Lean trunk	–2.87	–3.33 to –2.40	0.234	–7.55	1.81
Lean left arm	0.167	0.084 to 0.250	0.0419	–0.670	1.005
Lean right arm	–0.075	–0.168 to 0.017	0.0465	–1.004	0.853
Lean left leg	0.821	0.641 to 1.002	0.0909	–0.996	2.638
Lean right leg	0.614	0.438 to 0.790	0.0889	–1.163	2.391
Bone mineral content	0.740	0.660 to 0.820	0.0405	–0.070	1.550

compared DEXA scanning and bioimpedance in peritoneal dialysis patients [3], and most of these have concentrated on estimation of body water [22, 23]. Typically these studies were small, 10–40 patients [23, 24], and used single-frequency bioimpedance [3, 22], which has been shown to be less accurate than multifrequency bioimpedance [25].

One previous study, which used a more limited range of bioimpedance frequencies with 4 electrode contacts, reported a highly significant correlation between the two techniques for whole-body fat and FFM estimations [24], although Bland-Altman plots showed a marked variation between the two techniques [24]. This may have been due to technical differences and lower reliability of earlier bioimpedance equipment [25], but equally due to differences in DEXA scanning techniques [25, 26]. In addition MF-BIA, more than DEXA, is affected by volume status [23, 24], and this may partially explain the bias reported in this earlier study, which observed a negative bias for MF-BIA assessment of FFM, and a corresponding positive bias for FM compared to DEXA, as MF-BIA was performed with peritoneal dialysis fluid instilled into the abdomen [24]. In our study, the mean bias for total body measurements was much less than that in this earlier study, with MF-BIA having a small negative bias of –0.16 kg for FFM and a positive bias of 0.69 kg for FM. This bias is as expected, as DEXA and bioimpedance measure FM in different ways: DEXA measures fat, whereas MF-BIA measures the fat compartment and water component, so-called adipose water [27].

Compared to these earlier studies which were limited to whole-body assessments, we were able to assess not only total body but also segmental body composition, and showed a highly significant correlation between both methods, despite our study group having greater variation in body weights, habitus and ethnicity compared to previous studies [3, 23, 24]. Bias between the two methods was lowest for lean of the arms, greater for the legs and highest for the trunk, with MF-BIA overestimating the lean of the legs and underestimating the lean of the trunk. At the time of assessments, although there was no significant difference in weight, there was a mean difference of 0.5 kg. This could have been due to differences in hydration status between the assessments, even though we tried to standardise assessments by performing both measurements following drainage of peritoneal dialysate effluent, but cannot exclude small differences in residual peritoneal dialysate. MF-BIA is more likely to be affected by hydration status than DEXA. In addition, MF-BIA was performed with patients standing for 2 min, whereas DEXA was performed with patients supine, and the change in posture could potentially affect fluid status in the legs, which may account for the greater spread of results for the lean mass estimated in the legs compared to the arms. Greatest bias was observed with the trunk, which only contributes 9% of whole-body impedance, but >50% of FFM and body weight, and as such might not be adequately described by whole-body impedance [28], so accounting for the degree of bias observed between the two methods.

We noted that MF-BIA systematically overestimated the BMC in our peritoneal patients. This may be due to BMC not being directly measured by the MF-BIA, but derived from the LBM using an algorithm based on a general healthy population, rather than one with chronic kidney disease [29, 30]. Patients with chronic kidney failure are at increased risk of not only renal bone disease, but also of soft tissue calcification, in particular vascular calcification. Thus, DEXA scanning would appear to be more reliable than MF-BIA in assessing total BMC to exclude osteoporosis [31].

The key with any assessment of nutritional status is the ability to perform serial measurements to detect relative changes over time [32]. MF-BIA and to a lesser extent DEXA overestimate LBM in overhydrated patients [23], and therefore measurements should be made at a constant hydration status. Although MF-BIA cannot be performed in patients with amputations, pacemakers and implantable defibrillators, the advantage of MF-BIA is that it can be readily repeated, and previous studies have confirmed the reliability and reproducibility of the technique [28, 32]. Previous studies have validated the 8-point electrode MF-BIA for assessing body composition in haemodialysis patients [16, 33]. Our study supports the use of MF-BIA in assessing the body composition of peritoneal dialysis patients, and serial assessments could potentially be used to monitor changes in body composition to detect protein energy wasting. However, DEXA remains a more reliable assessment of bone mineral content.

Disclosure Statement

The authors have no conflicts of interest to disclose. The data contained in this article have not been previously published in whole or part (abstract) form.

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