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CLINICAL REPORT

# Validity of Bioelectrical Impedance Analysis to Estimate Body Composition Changes After Bariatric Surgery in Premenopausal Morbidly Women

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**Abstract** In obese patients, subtle variations of the hydration of soft tissues can propagate errors in bioelectrical impedance analysis (BIA) measures of body composition. Bioelectrical impedance vector analysis (BIVA) is a useful method to evaluate tissue hydration. Laparoscopic adjustable gastric banding (LAGB) is a purely restrictive bariatric surgical procedure resulting in lower fat-free mass (FFM) loss than other malabsorptive or mixed intervention. The aim of this study was to evaluate the 6- and 12-month changes in body composition in a homogeneous group of premenopausal morbidly obese women treated by LAGB by comparing the results of conventional BIA and BIVA with dual-energy X-ray absorptiometry (DXA) method. Forty-five consecutive morbidly obese patients (mean age, 35.3±9.1 years; body mass index, 34.5–48.7 kg/m$^2$) were prospectively evaluated at the Endocrinology Unit of the Department of Molecular and Clinical Endocrinology and Oncology. The LAGB device (Lap-Band™ System; Inamed Health, Santa Barbara, CA, USA) was inserted laparoscopically. Soft tissue hydration was evaluated by BIVA; fat mass (FM) and FFM were evaluated by BIA (BIA 101 RJL, Akern Bioresearch, Firenze, Italy) and by DXA (Hologic QDR 4500A S/N 45622; Hologic Inc., Bedford, MA, USA). Pre- and postoperative BIVA vectors indicated a normal hydration in all patients. Postoperatively, the excess of body weight loss was mainly due to a decrease in FM. The regression analysis of BIA and DXA methods at baseline and at the 6- and 12-month follow-up for FM $r^2$ values were 0.98, 0.94, and 0.99, respectively ($p<0.001$); FM% $r^2$ values were 0.91, 0.89, and 0.98, respectively ($p<0.001$); and FFM $r^2$ values were 0.87, 0.82, 0.99, respectively ($p<0.001$). BIA and DXA measurements of body composition exhibit a high relative agreement in the study group of normo-hydrated obese subjects. BIA tends to overestimate FFM, but this effect is reduced along with the weight loss during the follow-up. Under the stable hydration, the BIA method may be useful as an alternative to DXA in a selected clinical setting when repeated comparisons of body composition are required.

**Keywords** BIA · DXA · Morbid obesity · Body composition changes · LAGB

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## Introduction

Assessment of body composition plays an important role in clinical evaluation and in monitoring absolute and relative changes in fat mass (FM) and fat-free mass (FFM) during specific therapeutic regimens in obese subjects. Many technologies are available to measure body composition. Dual-energy X-ray absorptiometry (DXA) is used extensively for the assessment of body composition and is considered valid and reliable [1]. However, the wide application of this method is limited by requirements for expensive equipment, trained technicians, and dedicated facilities. Bioelectrical impedance analysis (BIA) represents a simple, inexpensive, and non-invasive means of assessing body composition with broad application in clinics and in weight reduction programs [2, 3]. Moreover, BIA does not have weight restriction limiting its use with all extreme obese population. Several studies have compared predictions of body composition by BIA with measurements made by reference methods [4, 5], but the results are contradictory, likely due to the confounding effects of multiple variables related to the clinical setting, such as range of body mass index (BMI) values and age, sex, and different diseases in the various series [4–8]. In particular, both over- and underestimation of percentage of FM (%FM) have been reported, whereas other studies showed good agreement between BIA and DXA. Thus, extent of the bias when compared with DXA remains unanswered. In particular, in obese patients, subtle variations of the hydration of soft tissues can propagate errors in the prediction of body composition from the reference methods to the predictive equations used in conventional BIA [9, 10]. Bioelectrical impedance vector analysis (BIVA) and the RXc graph is a useful method to check for changes in tissue hydration [11–13].

Laparoscopic adjustable gastric banding (LAGB) is a purely restrictive bariatric surgical procedure [14] effective in improving obesity-related co-morbidities and resulting in lower FFM loss than other malabsorptive or mixed intervention [15, 16]. Among several studies analyzing body composition and fat distribution in obese subjects after LAGB [15–19], no studies reported the body composition by simultaneous DXA, BIA, and BIVA evaluation of during the follow-up. In this study, we evaluated the 6- and 12-month changes in body composition in a homogeneous group of premenopausal morbidly obese women treated by LAGB associated to a well-balanced low-calorie diet by comparing against each other the results of conventional BIA and BIVA for prediction of body composition with DXA methods.

## Subjects and Methods

We prospectively evaluated 45 consecutive morbidly obese patients (mean age, 35.3±9.1 years) among over 100 severely obese women referred to the Endocrinology Unit of the Department of Molecular and Clinical Endocrinology and Oncology from 2006 to 2009. To reduce the hormonal interference on body composition, premenopausal obese women only were included in this study. Patients were considered to be premenopausal if they have had at least ten menstrual periods in the previous year, the last one less than 60 days before the baseline examination. An extensive clinical and hormonal endocrine evaluation allowed to exclude patients with endocrine diseases. None of the patients was receiving drug treatments at the time of the assessment. Patients were selected for LAGB according to the inclusion criteria standardized by the National Institutes of Health [20]. The study design was in accordance with the Helsinki Declaration. All the subjects gave their informed consent to the study that was approved by the Ethical Committee of the Medical School of the University Federico II of Naples. All patients underwent a comprehensive pre- and postoperative psychiatric evaluation conducted by a behaviorist who has expertise in bariatric patient management. This assessment included personal and social history, history of psychiatric problems, current living situation, and support system. None had any evidence of psychiatric diseases.

The adjustable gastric banding device (Lap-Band™ System; Inamed Health, Santa Barbara, CA, USA) was inserted laparoscopically according to Angrisani et al. [21]. To minimize postoperative vomiting, the band was left completely unfilled at surgery [22]. The band was gradually inflated after weight stabilization (<4 kg of weight lost in the last month). At discharge, patients were instructed to follow a solid diet of "permitted" foods and a list of rules specifically developed for patients with gastric restriction [23]. Patients were evaluated preoperatively, 6 and 12 months after LAGB ($T_0$, $T_6$, and $T_{12}$), an interval over which, in our experience and according to other reports [24], the rate of weight loss is greater than in subsequent periods. After surgery, patients followed a diet specifically devised for LAGB recipients: semi-liquid for 4 weeks and solid (supplying 5.7 MJ/die: 25% fat, 20% protein, and 55% carbohydrates). The solid diet contained an inventory of the foods permitted and a list of rules specifically developed for patients with gastric restriction [22, 23]. The physical activity was encouraged; it consisted primarily of 60 to 90 min per day of moderate-intensity activity (e.g., brisk walking). The band was tightened in case of weight stabilization (<4 kg of weight lost in the last month), providing that a solid food item per meal was ingested and a low vomiting frequency was observed. No more than one adjustment per month was performed, and no more than 1.5 ml of sterile saline was added in each step. Band competence was always controlled with a barium swallow before and after the adjustment.

Compliance was reviewed monthly by a multidisciplinary team of endocrinologists, dieticians, psychiatrists, and surgeons. Anthropometry, body composition, and dietary intake were evaluated at the same time of the day with the subjects in a non-fasting state, before and 6 and 12 months after LAGB.

Baseline weight, height, and BMI were measured in all subjects. No correction for clothing weight was applied. Body weight (BW), in light indoor clothing, was measured to the nearest 0.1 kg using digital scales and height to the nearest 0.1 cm with the subjects wearing swimming costumes. BMI was calculated from weight and height (kg/m$^2$). Daily caloric intake and diet composition were calculated during a personal interview using a detailed food-frequency questionnaire of 130 foods and beverages [25]. All evaluations were part of the routine patients' treatment. Calculated indexes were

- Ideal body weight (IBW) was derived from 1983 Metropolitan Height and Weight tables
- Excess body weight (EBW): BW−IBW
- Percent of excess body weight loss (%EBWL) after surgery: (BW loss/EBW)×100.

### Bioelectrical Impedance Analysis (BIA) and Bioelectrical Impedance Vector Analysis (BIVA)

Body composition was determined by conventional BIA and by BIVA by a single investigator with a single-frequency 50 kHz bioelectrical impedance analyzer (BIA 101 RJL, Akern Bioresearch, Firenze, Italy) according to the standard tetrapolar technique, with the subject in supine position and the electrodes placed on the dorsal surface of right foot and ankle, and right wrist and hand. Patients were evaluated after an overnight fasting, after emptying the bladder, and were asked to refrain from strenuous exercise and to maintain their usual intake of caffeinated beverages during the 3 days preceding the measurements. Weight and height were recorded, and a clinical examination was performed. Body composition was calculated from bioelectrical measurements and anthropometric data by applying the software provided by the manufacturer, which incorporated validated predictive equations for total body water (TBW), FM, and FFM [26, 27]. Normal values for females <50 years are reported in Table 3. Soft tissue hydration of individual subjects was evaluated as impedance vectors in the Resistance (R)–Reactance (Xc) Graph by BIA Vector, a stand-alone procedure based on patterns of direct impedance measurements (impedance vectors), by using the BIVA software [Piccoli A, Pastori G (2002). BIVA software. Department of Medical and Surgical Sciences, University of Padova, Italy (available at E-mail: apiccoli@unipd.it)]. R and Xc were normalized by the height of subjects (R/H and Xc/H), and the resulting vectors were plotted on a graph reporting the gender-specific 50th, 75th, and 95th tolerance ellipses of similar vectors calculated from a reference healthy population [11, 26, 27]. According to the RXc graph method, vectors falling within the reference gender-specific 75th tolerance ellipse indicated normal hydration, short vectors (below the lower pole of the 75th tolerance ellipse) indicated overhydration, and long vectors (above the upper pole of the 75th tolerance ellipse) indicated underhydration. Vector position was also compared with the fat-fluid linear threshold discriminating between short vectors from either edematous or obese subjects falling out of the lower pole of the reference 75% tolerance ellipse, with vectors from obese subjects without edema expected to fall above the fat-fluid threshold and vectors from edematous patients that expected to fall below the fat-fluid threshold [24, 27]. Vector's length was calculated as $|Z| = \sqrt{\left[(R/H)^2 + (Xc/H)^2\right]}$, and vector's phase angle as the arctan of Xc/R.

### Dual-energy X-ray Absorptiometry

Whole-body FFM (DXA lean body mass plus bone) was determined by an experienced technician using DXA (Hologic QDR 4500A S/N 45622; Hologic Inc., Bedford, MA, USA) with software version 12.4. Maximum weight limit was 130 kg. Scans were performed by a trained technician while subjects were in a supine position. Whole-body scan time was less than 2 min, and the radiation was 1 millirem. The mean coefficients of variation for the repeated DXA analyses were provided by company and were total body mineral density, 0.84%; FM, 2.20%; and FFM, 0.86%. Reliability of the DXA was assessed by phantom scans throughout the duration of the study. All scans were performed by the same DXA operator blind in respect to patients' treatment. FFM was indirectly calculated as weight minus bone mineral content minus FM.

### Statistic Analysis

Values are given as mean±SD unless otherwise specified. Differences in repeated measures of FM, %FM, and FFM between the BIA and DXA methods at the 6- and 12-month follow-up vs baseline were tested by using one-factor analysis of variance and were corrected based on the Bonferroni post hoc test. The correlation between FM, %FM, and FFM values predicted by BIA and that measured by DXA was estimated by the use of Pearson's correlation. The pairs of FM, %FM, and FFM value means have been also used to compare BIA and DXA measurements based on the 95% limits of agreement for the difference of the means according to Bland–Altman method [28]. $P$ values <0.05 were considered significant. Data were stored and analyzed using the Statistical Package for Social Science (SPSS) program (release 13.0; SPSS Inc, Chicago, IL, USA).

## Results

Anthropometry and body composition of the patients before and after surgery were reported in Tables 1 and 2. At baseline, BMI ranged from 34.5 to 48.7 kg/m$^2$. No postoperative complications occurred in these patients. Dietary intake based on interviewer-administered questionnaire was reported in Table 2. After surgery, a significant reduction in food intake was observed at the repeated dietary assessments, and the composition of the diet fit quite well with dietary prescriptions, with a good nutritional compliance. None of the treated subjects dropped out of the study.

In the first 6 months after surgery, the mean weight loss was 15.6±6.4 kg, and loss of FM and FFM evaluated by BIA represented 14.7±5.0 and 1.0±3.7 kg, respectively, while loss of FM and FFM evaluated by DXA represented 13.7±6.8 and 1.1±3.7 kg, respectively. From 6 to 12 months, a further 12.3±5.8 kg of BW were lost (11.8±5.6 kg of FM and 0.5±3.9 kg of FFM by BIA and 12.4±6.4 kg of FM and 0.2±4.3 kg of FFM by DXA). The EBWL observed after LAGB was mainly due to a decrease in FM, whereas TBW and FFM were not significantly reduced.

The soft tissue hydration was evaluated according to the RXc graph method in Fig. 1. Before surgery, no patients' vectors were below the boundary line threshold discriminating between the obese and the oedematous, indicating a normal hydration. All vectors fell in the lower left quadrant, out of the boundary line of 75th tolerance ellipse, as expected in morbidly obese patients with normal hydration. The bioelectrical measurements (R, Xc, phase angle, and length of the vectors) before and after surgery were reported in Table 3. No significant differences in *R* and in the vector length were observed during the follow-up, indicating no significant changes in the hydration status of the patients. The regression analysis of BIA and DXA methods for each values at baseline and at the 6- and 12-month follow-up for FM $r^2$ values were 0.98±1.63 SE, 0.94±2.21 SE, and 0.99±0.30 SE, respectively ($p<0.001$); %FM $r^2$ values were 0.91±3.02 SE, 0.89±3.88 SE, and 0.98±1.04 SE, respectively ($p<0.001$); and FFM $r^2$ values were 0.87±3.83 SE, 0.82±4.13 SE, 0.99±0.98 SE, respectively ($p<0.001$; Fig. 2). The Bland–Altman plots are given in Fig. 3.

## Discussion

The principal aim of this study was to investigate the accuracy of BIA method, using DXA as the reference method, in determining body composition in a small group of morbidly obese women during a 12-month follow-up after LAGB associated with a well-balanced hypocaloric diet. The results show that the BIA assessments of body composition provided a good relative agreement with DXA, as indicated by high correlation coefficients and by the 95% limits of agreement for the difference evidenced in the Bland–Altman plots. In particular, along with a highly significant 50.5% reduction of EBW at 12 months, in our study group using both methods, we observed a predominantly loss of FM, without a significant loss of FFM or body fluid alterations. As a matter of fact, we evidenced the correlation coefficients were lower in evaluating BIA and DXA-FFM compared to BIA and DXA-FM and %FM at $T_0$ and $T_6$, while this difference disappeared at $T_{12}$. These results were found notwithstanding the possible overestimation suffered by the BIA method in the measurement of FFM. This finding is comparable with previous studies, which have reported a same high correlations between BIA and DXA-FM and %FM in overweight or obese popula-

**Table 1** Anthropometry and body composition estimated by bioelectrical impedance analysis and dual-energy X-ray absorptiometry in 45 morbidly obese women before and 6 and 12 months after laparoscopic adjustable gastric banding

| | BW (kg) | BMI (kg/m$^2$) | %EBWL | TBW (l) | | FM (kg) | FM% | FFM (kg) |
|---|---|---|---|---|---|---|---|---|
| $T_0$ | 115.8±13.5 | 42.1±4.1 | – | 42.0±2.7 | BIA | 55.6±11.7 | 47.6±5.1 | 60.3±5.1 |
| | | | | | DXA | 55.0±11.2 | 46.9±5.0 | 60.1±6.1 |
| $T_6$ | 100.2±13.7* | 38.0±7.8* | 40.9±12.9 | 41.9±3.4 | BIA | 40.9±12.0* | 42.0±6.5* | 59.3±5.5 |
| | | | | | DXA | 41.2±11.4* | 42.5±5.0* | 59.1±6.8 |
| $T_{12}$ | 88.0±13.6** | 33.4±7.5** | 28.7±12.9** | 41.4±2.9 | BIA | 29.1±9.8** | 37.2±5.7** | 58.8±5.5 |
| | | | | | DXA | 28.2±9.1** | 37.0±5.3** | 59.3±5.7 |

$p<0.001$ vs $T_0$

$T_0$ baseline, $T_6$ after 6 months, $T_{12}$ after 12 months, *%EBWL* percent of excess body weight loss, *FM* fat mass, *FM%* fat mass percentage, *FFM* fat-free mass, *TBW* total body water

*$p<0.05$ vs$T_0$

**$p<0.001$ vs $T_6$

**Table 2** Dietary intake based on interviewer-administered questionnaire in 45 morbidly obese patients before and 6 and 12 months after laparoscopic adjustable gastric banding

| | Before | 6months | 12months |
|---|---|---|---|
| Energy intake, MJ/die | 12.3±1.9 | 5.8±1.2* | 6.1±1.8* |
| Energy intake, Kcal/die | 2,950±454 | 1,380±286* | 1,460±430* |
| Total carbohydrate, % energy | 45.6±10.5 | 53.8±9.5 | 52.1±8.5 |
| Total fat, % energy | 37.5±7.6 | 27.8±5.7* | 26.3.±5.9* |
| Total protein, % energy | 16.5±3.8 | 19.5.±5.7 | 20.6±4.2 |

All values are mean±SD. Significantly differences (one-factor analysis of variance)

*$p<0.05$ vs baseline

tions and, although to a lesser extent, for DXA-FFM and BIA-FFM [29–34]. However, for the BIA method, all the correlations were highest at the end of the study ($T_{12}$). Therefore, a general good agreement was obtained between all the BIA and DXA variables examined, and the accuracy of BIA method was higher along with the weight reduction during the follow-up.

Along with the increased acceptance of surgical procedures for weight loss in morbid obesity, clinically useful baseline and follow-up measures of body composition are critical to evaluate interventional outcomes. BIA is an attractive method for repeated measurements of body composition in vivo, because it is non-invasive, simple, and cheap. Previous studies evidenced alternatively under- and overestimation in BIA-FFM compared with DXA-FFM in normal weight and obese subjects, respectively [4–8, 29–34]. This bias, however, likely depends on the large range of BMI of the subjects enrolled in these studies. The presence of a systematic error between DXA and BIA in FFM estimation is generally related to different body geometry and perturbation in fluid content that occur with varying levels of body fat, and that can propagate errors in the prediction of body composition from the reference methods through the theory algorithm used in conventional BIA to calculate body water volumes and, hence, FFM [9, 10]. A recent study compared the validity of segmental multiple-frequency-BIA and DXA in healthy adults stratified by BMI and evidenced an overestimation in %FM in the obese group [35]. However, although the accuracy of the BIA method in the determination of the changes in body composition in obese patients loosing weight has been criticized, no data are available on BIA/DXA correlations in morbidly obese individuals after bariatric surgery.

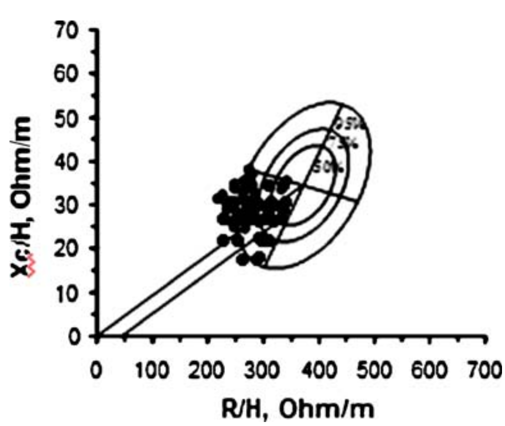


**Fig. 1** Resistance (R)–reactance (Xc) graph. The individual impedance vectors in 45 morbidly obese women before Lap-Band™ adjustable gastric banding were plotted on the reference 50th, 75th, and 95th tolerance ellipses of a reference healthy population using bioelectrical impedance analysis vector analysis as direct measurements of body impedance

Our study design featured some aspects that improved on previous investigations. First, our sample size of 45 subjects represented a very homogeneous group. In fact, one of the limits of utility of BIA for accurately determining body composition in any given individual, and its use, therefore, is represented by the clinical setting. In the present study, the subjects participating were healthy female, albeit morbidly obese, within a restricted age and BMI range, all in premenopausal stage, and evaluated in the same phase of their menstrual cycle. Second, all subjects of the study group underwent to the same bariatric intervention associated to a well-balanced low-calorie diet. In particular, a more conservative band management (band left unfilled at surgery and very prudent postoperative band inflation) consented a reduction in vomiting frequency and an easier ingestion of solid foods [21, 22], facilitating the patient to comply with a well-balanced hypocaloric diet. In that, the repeated dietary assessments demonstrated a good nutritional compliance. Third, to minimize the systematic errors between DXA and BIA, in this study, we used BIVA and the RXc graph method to check for changes in tissue hydration. A recent study documented the invariability of the impedance vector length after an energy-restricted diet leading to pure FM loss [24] and a lengthening of the

**Table 3** Bioelectrical impedance analysis measurements in 45 morbidly obese women before and 6 and 12 months after laparoscopic adjustable gastric banding

| | R (Ohm) | R/H (Ohm/m) | Xc (Ohm) | Xc/H (Ohm/m) | Phase angle (°) | Vector length (Ohm/m) |
|---|---|---|---|---|---|---|
| $T_0$ | 435.0±41.7 | 260.1±27.5 | 52.0±5.1 | 31.1±3.2 | 6.6±0.6 | 265.3±25.5 |
| $T_6$ | 441.1±45.0 | 265.5±29.5 | 54.2±6.2 | 32.3±3.8 | 6.7±0.8 | 272.3±30.6 |
| $T_{12}$ | 455.4±50.0 | 272.3±32.4 | 54.9±3.9* | 32.8±2.6* | 6.6±0.6 | 274.0±33.5 |
| Normal values | | 371±49 | | 34.4±7.7 | 5–6 | |

$T_0$ baseline, $T_6$ after 6 months, $T_{12}$ after 12 months, *R* resistance, *Xc* reactance
*$p<0.05$ vs $T_0$

impedance vector predicted FFM loss in obese subjects loosing weight [31]. Based on this new method, we demonstrated a normo-hydration status at baseline and no changes in body hydration after surgery, as indicated by the unchanged length of the impedance vector. Short-term maintenance of FFM with only very mild body fluids alterations after LAGB was confirmed by absorptiometry and dilution methods [18]. Moreover, as the effects of hydration status and body geometry with increasing obesity may explain the systematic errors between DXA and BIA,

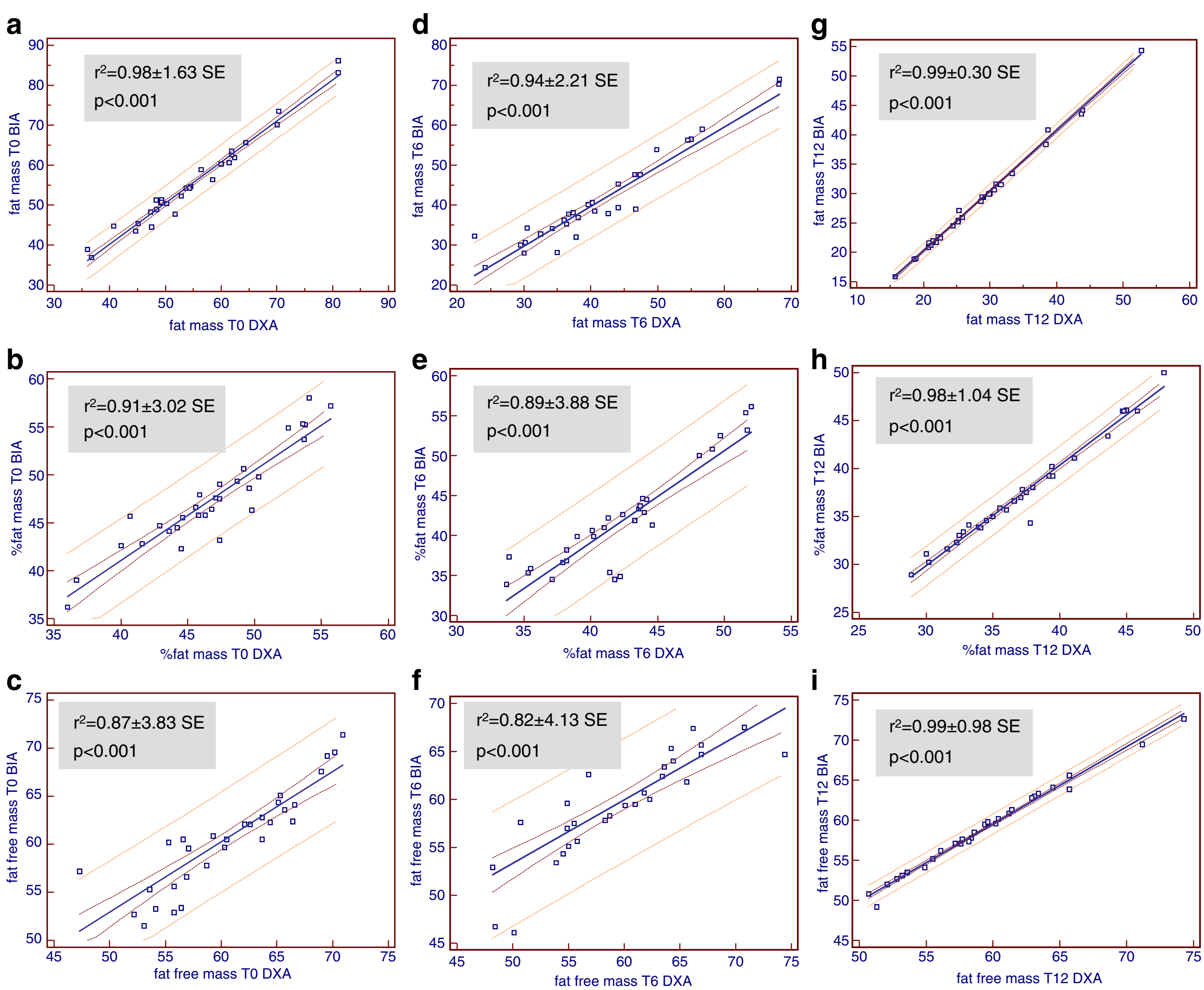


**Fig. 2** Regression analysis of bioelectrical impedance analysis and dual-energy X-ray absorptiometry measurements of fat mass (FM), percentage of fat mass (%FM), and fat-free mass (FFM) at baseline (T0; **a**–**c**), and during the follow-up at 6 (T6; **d**–**f**) and 12 months (T12; **g**–**i**)

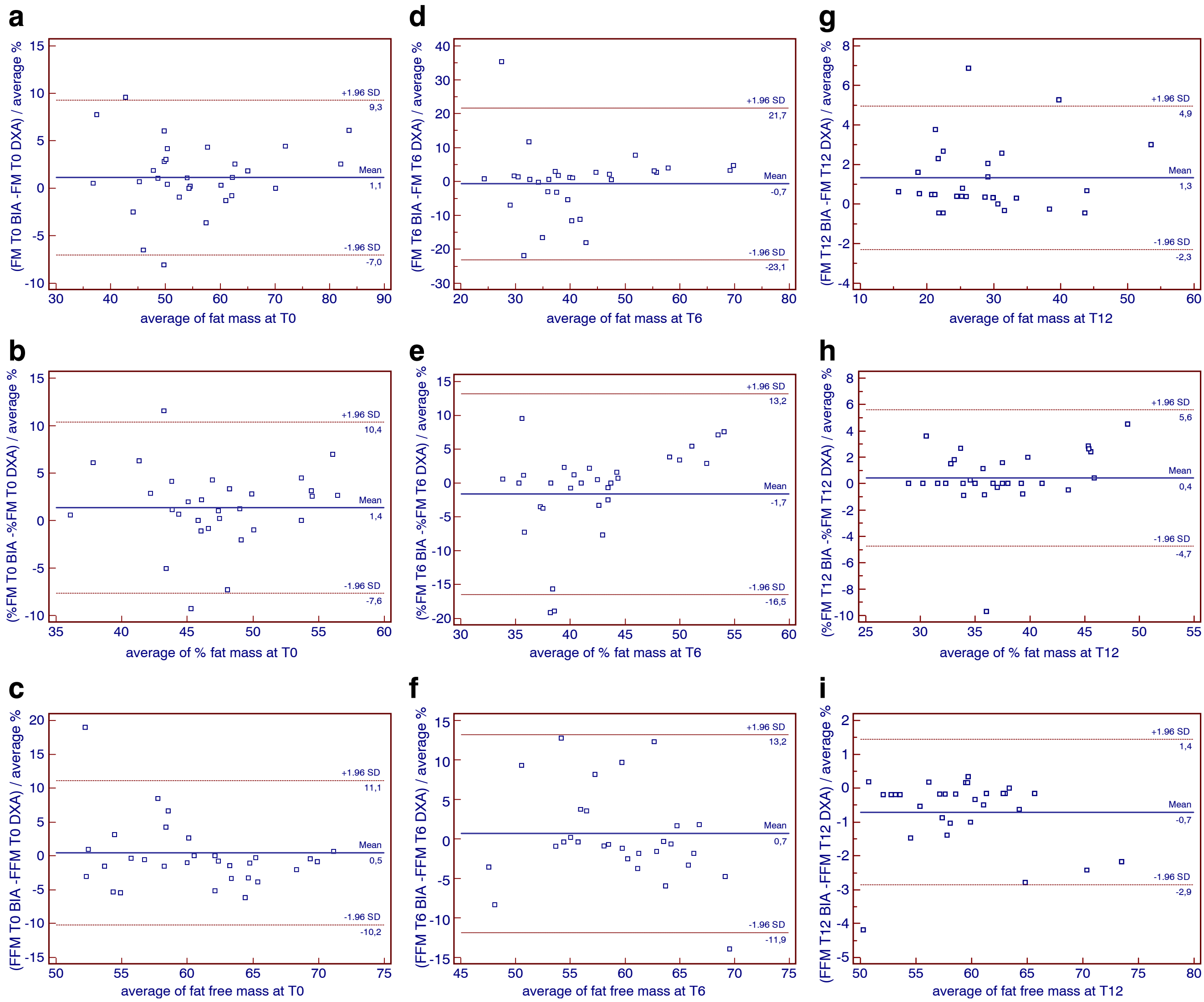


**Fig. 3** Bland–Altman plots of the difference between bioelectrical impedance analysis and dual-energy X-ray absorptiometry measurements of fat mass (FM), percentage of fat mass (%FM), and fat-free mass (FFM) at baseline (T0; **a**–**c**), and during the follow-up at 6 (T6; **d**–**f**) and 12 months (T12; **g**–**i**)

our data evidenced that this effect is reduced along with the reduction of BMI values during the follow-up. Therefore, in the present study, the limitation of BIA method to evaluate body composition in obese patients can be also overcome by the length of follow-up.

In conclusion, the major contribution of the present study is the demonstration that parallel measurement of body composition by BIA and DXA exhibit a good relative agreement when a homogeneous normo-hydrated group of obese subjects is evaluated by repeated measures of body composition after LAGB and mild hypocaloric diet. This finding is comparable with previous studies, which have reported high correlations between DXA and BIA also in overweight or obese populations. Although BIA tends to overestimate FFM, this bias, however, depends on the degree of adiposity, and our data evidence that this effect is reduced along with the weight loss during the follow-up. Thus, the evidence presented here limits the utility of BIA for accurately determining body composition in any given individual, but confirms that, although BIA data are not yet universally applicable to all subject groups, under the stable hydration, the BIA method may be useful as an alternative to DXA in a selected clinical setting when repeated comparisons of body composition are required.

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## References


1. Plank LD. Dual-energy X-ray absorptiometry and body composition. Curr Opin Clin Nutr Metab Care. 2005;8:305–9.
2. Lukaski HC, Johnson PE, Bolonchuk WW, et al. Assessment of fat-free mass using bioelectrical impedance measurements of the human body. Am J Clin Nutr. 1985;41:810–7.
3. Lukaski HC, Siders WA. Validity and accuracy of regional bioelectrical impedance devices to determine whole-body fatness. Nutrition. 2003;19:851–7.
4. Fogelholm M, van Marken Lichtenbelt W. Comparison of body composition methods: a literature analysis. Eur J Clin Nutr. 1997;51:495–503.
5. Jaffrin MY, Morel H. Body fluid volumes measurements by impedance: a review of bioimpedance spectroscopy (BIS) and bioimpedance analysis (BIA) methods. Med Eng Phys. 2008;30:1257–69.
6. Pateyjohns IR, Brinkworth GD, Buckley JD, et al. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity. 2006;14:2064–70.
7. Thomson R, Brinkworth GD, Buckley JD, et al. Good agreement between bioelectrical impedance and dual-energy X-ray absorptiometry for estimating changes in body composition during weight loss in overweight young women. Clin Nutr. 2007;26:771–7.
8. Minderico CS, Silva AM, Keller K, et al. Usefulness of different techniques for measuring body composition changes during weight loss in overweight and obese women. Br J Nutr. 2008;99:432–41.
9. Baumgartner RN, Ross R, Heymsfield SB. Does adipose tissue influence bioelectric impedance in obese men and women? J Appl Physiol. 1998;84:257–62.
10. Deurenberg P. Limitations of the bioelectrical impedance method for the assessment of body fat in severe obesity. Am J Clin Nutr. 1996;64:449S–52.
11. Piccoli A, Rossi B, Pillon L, et al. A new method for monitoring body fluid variation by bioimpedance analysis: the RXc graph. Kidney Int. 1994;46:534–9.
12. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Composition of the ESPEN Working Group. Bioelectrical impedance analysis—part I: review of principles and methods. Clin Nutr. 2004;23:1226–43.
13. Lukaski HC, Hall CB, Siders WA. Assessment of change in hydration in women during pregnancy and postpartum with bioelectrical impedance vectors. Nutrition. 2007;23:543–50.
14. Kral JG, Näslund E. Surgical treatment of obesity. Nat Clin Pract Endocrinol Metab. 2007;3:574–83.
15. Chaston TB, Dixon JB, O'Brien PE. Changes in fat-free mass during significant weight loss: a systematic review. Int J Obes. 2006;31:743–50.
16. Sergi G, Lupoli L, Busetto L, et al. Changes in fluid compartments and body composition in obese women after weight loss induced by gastric banding. Ann Nutr Metab. 2003;47:152–7.
17. Coupaye M, Bouillot JL, Poitou C, et al. Is lean body mass decreased after obesity treatment by adjustable gastric banding? Obes Surg. 2007;17:427–33.
18. Strauss BJ, Marks SJ, Growcott JP, et al. Body composition changes following laparoscopic gastric banding for morbid obesity. Changes in body composition and insulin sensitivity in severely obese subjects after laparoscopic adjustable silicone gastric banding (LAGB). Acta Diabetol. 2003;40:S266–9.
19. Garrapa GG, Canibus P, Gatti C, et al. Is lean body mass decreased after obesity treatment by adjustable gastric banding? Med Sci Monit. 2005;11:CR522–8.
20. Gastrointestinal Surgery for severe obesity. National Institutes of Health Consensus Development Conference Draft Statement. Obes Surg. 1991;1:257–66.
21. Angrisani L, Lorenzo M, Esposito G, et al. Laparoscopic adjustable silicone gastric banding: preliminary results of Naples experience. Obes Surg. 1997;7:19–21.
22. Busetto L, Pisent C, Segato G, et al. The influence of a new timing strategy of band adjustment on the vomiting frequency and the food consumption of obese women operated with laparoscopic adjustable silicone gastric banding (LAP-BAND®). Obes Surg. 1997;7:505–12.
23. Busetto L, Valente P, Pisent C, et al. Eating pattern in the first year following adjustable silicone gastric banding (ASGB) for morbid obesity. Int J Obes. 1996;20:539–46.
24. Guida B, Belfiore A, Angrisani L, et al. Laparoscopic gastric banding and body composition in morbid obesity. Nutr Metab Cardiovasc Dis. 2005;15:198–203.
25. Hu FB, Rimm E, Smith-Warner SA, et al. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. Am J Clin Nutr. 1999;69:243–9.
26. Piccoli A, Nigrelli S, Caberlotto A, et al. Bivariate normal values of the bioelectrical impedance vector in adult and elderly population. Am J Clin Nutr. 1995;61:269–70.
27. Piccoli A, Brunani A, Savia G, et al. Discriminating between body fat and fluid changes in the obese adult using bioimpedance vector analysis. Int J Obes. 1998;22:97–104.
28. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986;i:307–10.
29. Andreoli A, Melchiorri G, De Lorenzo A, et al. Bioelectrical impedance measures in different position and vs dual-energy X-ray absorptiometry (DXA). J Sports Med Phys Fitness. 2002;42:186–9.
30. Sun G, French CR, Martin GR, et al. Comparison of multifrequency bioelectrical impedance analysis with dual-energy X-ray absorptiometry for assessment of percentage body fat in a large, healthy population. Am J Clin Nutr. 2005;81:74–8.
31. Frisard MI, Greenway FL, Delany JP. Comparison of methods to assess body composition changes during a period of weight loss. Obes Res. 2005;13:845–54.
32. Pateyjohns IR, Brinkworth GD, Buckley JD, et al. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity. 2006;14:2064–70.
33. Ward LC, Dyer JM, Byrne MN, et al. Validation of a three-frequency bioimpedance spectroscopic method for body composition analysis. Nutrition. 2007;23:657–64.
34. Strain GW, Wang J, Gagner M, et al. Bioimpedance for severe obesity: comparing research methods for total body water and resting energy expenditure. Obesity. 2008;16:1953–6.
35. Shafer KJ, Siders WA, Johnson LK, et al. Validity of segmental multiple-frequency bioelectrical impedance analysis to estimate body composition of adults across a range of body mass indexes. Nutrition. 2009;25:25–32.