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Original

Comparison of different body composition mesurements in severely obese patients in the clinical setting

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Abstract

Background & Aims: Body composition measurements seem to be not reliable enough in obese patients. Our aim was to compare single frequency-bioelectrical impedance (SF-BIA) analysis; foot-to-foot impedance meters (FFI) or upper body fat analysers (UBFA) and DXA (Dual-energy X-ray absorptiometry) in severely obese patients.

Patients and methods: Cross-sectional study including 40 severely obese patients. Bioelectrical impedance was performed for SF-BIA (Holtain (H) and OMRON BF 500 (O500)), FFI (Tanita TBF-300 (T)) and UBFA (Omron BF 300 (O300)). DXA scans were performed using a Lunar iDXA. The data were analysed using Pearson's correlation and Bland Altman plots were also drawn to evaluate any agreements.

Results: The percentage and total body fat values were 49.2% and 55.2 kg measured with DXA, 44.3%/53.4 kg with O300, 50.6%/58.3 kg with O500, 45.4%/55.4 kg with H and 49.1%/60.3 kg with T. The Holtain BIA showed the worst correlation with DXA for both %BF and FFM. Although the measurements of % body fat, fat mass and fat-free mass were significantly correlated with DXA, each method showed wide limits of agreement, although T was most closely correlated with DXA.

Conclusion: Compared to DXA, FFI and UBFA could be useful for assessing body composition in severely obese people, although they appeared to underestimate %BF and FM and their limits of agreement were too wide.

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Key words: *Obesity. Body composition. Nutritional assessment. Dual-energy X-ray absorptiometry. Bioelectrical impedance analysis.*

COMPARACIÓN DE LAS DIFERENTES MEDIDAS DE LA COMPOSICIÓN CORPORAL EN PACIENTES CON OBESIDAD GRAVE EN UN CONTEXTO CLÍNICO

Resumen

Introducción: La medida de la composición corporal parece no tener suficiente fiabilidad en los pacientes obesos. Nuestro objetivo fue comparar técnicas de impedancia monofrecuencia (SF-BIA), impedanciómetros de arco inferior (FFI) o de arco superior (UBFA) con densitometría (DXA) en pacientes con obesidad severa.

Pacientes y métodos: Estudio transversal de 40 pacientes con obesidad severa. Se realizó medida de composición corporal mediante impedancia bioeléctrica realizada con dos instrumentos de medida de impedancia monofrecuencia (Holtain (H) y OMRON BF 500 (O500)), FFI (Tanita TBF-300 (T)) y UBFA (Omron BF 300 (O300)). La densitometría para composición corporal se llevó a cabo en un DXA Lunar iDXA. Se analizaron los datos mediante correlación de Pearson y se empleó el método de Bland Altman para evaluar los acuerdos entre técnicas.

Resultados: Los valores absolutos y porcentajes grasa corporal fueron 49,2% y 55,2 kg medidos con DXA, 44,3%/53,4 kg con O300, 50,6%/58,3 kg con O500, 45,4%/55,4 kg con H y 49,1%/60,3 kg con T. El impedanciómetro tipo Holtain mostró la peor correlación con DXA, tanto para Porcentaje de grasa como masa libre de grasa. Aunque las medidas de porcentaje de grasa, masa grasa total y masa libre de grasa se correlacionaron con DXA de forma significativa, los límites de concordancia de cada método fueron demasiado amplios. T fue el método mejor correlacionado con DXA.

Conclusión: En comparación con DXA, FFI y UBFA podrían ser útiles para valorar composición corporal en pacientes obesos severos, aunque teniendo en cuenta que parecen infraestimar %BF y FM y que sus límites de concordancia son bastante amplios.

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Palabras clave: *Obesidad. Composición corporal. Evaluación nutricional. Absorciometría dual de rayos X. Impedancia bioeléctrica. Análisis de impedancia.*

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Abbreviations

BIA = Bioelectrical impedance.
BMI = Body mass index.
DXA = Dual-energy X-ray absorptiometry.
ECW = Extracellular water.
FFI = Foot-to-foot impedance meters.
FM = Fat mass.
FFM = Fat-free mass.
H = Holtain impedance meter.
ICW = Intracellular water.
MF-BIA = Multi-Frequency Bioelectrical Impedance Analysis.
SF-BIA = Single frequency-bioelectrical impedance analysis.
O300 = Omron BF 300.
O500 = OMRON BF 500.
T = Tanita TBF 300.
TBW = Total body water.
UBFA = Upper body fat analysers.
% BF = Percentage of body fat.

Background

Obesity is defined as an excessive accumulation of body fat. Severe obesity implies not only large increases in fat mass but also alterations in the composition of fat-free mass, in particular total body water and its extracellular compartment, which can cause difficulties in measuring fat. Anthropometric assessments are simple and cheap but they are neither easy to perform nor reliable enough to use on severely obese patients.[1] Bioelectrical impedance analysis (BIA) using single or multi-frequency BIA (MF-BIA) has been widely used in spite of its limitations in the severely obese population. It has been reported that single frequency-bioelectrical impedance (SF-BIA) analysis is not accurate enough in subjects with a BMI > 34 kg/m^2, nor are foot-to-foot impedance meters (FFI) or upper body fat analysers (UBFA), both of them also based on SF-BIA.[2,3] Dual-energy X-ray absorptiometry (DXA) has been considered the gold standard for body composition measurements in obese people. The aim of our study was to compare total weight, % body fat (% BF), fat mass (FM) and fat-free mass (FFM) measured by BIA and DXA in severely obese people in a real clinical setting.

Patients and methods

Cross-sectional study including 40 severely obese patients who were consecutively recruited in the Endocrinology and Nutrition Department of Complejo Asistencial Universitario de León (Spain). The inclusion criteria comprised patients in the Obesity Clinic whose body mass index was greater than 40 kg/m^2 and who were 18 to 60 years old. Pregnant women were excluded. Patients who were heavier than 150 kg were also excluded because of limitations to the DXA study. A total of 58 patients were screened and 18 were excluded because they were heavier than 150 kg. The study was approved by the Ethics and Clinical Investigation Committee of the hospital and written informed consent from each of the 40 patients who agreed to participate was obtained by the physician responsible for them. The body composition studies were carried out in one morning, after overnight fasting and without previous exercise, alcohol or stimulant beverages.

Bioelectrical impedance was performed using SF-BIA (Holtain (H) and an OMRON BF 500 (O500) (Omron Corp., Kyoto, Japan). H uses electrodes placed in arms and legs with the patient in a lying position. O500 combines electrodes mounted on handles for the hands in addition to plantar electrodes in a body scale, so it measures the resistances of the limbs and trunk with a single frequency current. The foot-to-foot BIA was measured using a Tanita body composition analyser (model TBF-300; Tanita Corp., Tokyo, Japan), which provides a printout of measured impedance, calculated body fat and fat-free mass. This device consist on a body scale used in upright position with four contact electrodes under the feet. The single-frequency current only circulates in the legs and the lower part of the trunk, so it extrapolates results for the whole body using a proprietary equation of resistance, weight, height, age and sex. The hand-to-hand BIA was measured using the Omron BF300 (O300)(Omron Corp., Kyoto, Japan), which provides absolute and percentage body fat measurements, but not fat-free mass. O300 is a UBFA which has only digital electrodes for finger contact in the hands, and measurements are taken with arms extended horizontally. The DXA total body scans were performed using a Lunar iDXA (GE Healthcare). The DXA equipment consists of a table with a mobile arm in which the individual, in the supine position, is swept from the cranium down. An X-ray source is located in one extreme of the arm while an emergent radiation detector is in the opposite detector. The same laboratory technician positioned the subjects, performed the scans and executed the analysis according to the operator's manual and using the standard analysis protocol. The DXA analysis provides fat mass, fat-free mass and bone mass data for the whole body and also for its different segments.

The data were analysed using SPSS for Windows version 15.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics including mean values and standard deviations (shown in parentheses) were calculated for age, BMI, %BF, FM and FFM. After checking for normal distribution of the data, Pearson's correlation was used to calculate the relationship between FM, %BF, and FFM. Bland-Altman plots were also drawn to evaluate any agreement between the different methods, including the 95% limits of agreement (mean difference ± 1.96 SD), using MedCalc 11.6.1.0. (MedCalc Software bvba, Belgium). The differences between each method and DXA against

	% BF*	FM*	FFM*
OMRON BF 300	44.3% (4.7) r = 0.782	53.4 kg (9.3) r = 0.800	–
OMRON BF 500	50.6% (7.1) r = 0.892	58.3 kg (9.3) r = 0.888	–
HOLTAIN	45.4% (7.9) r = 0.710	55.4 kg (12.8) r = 0.815	66.7 kg (13.9) r = 0.783
Tanita TBF 300	49.1% (4.7) r = 0.810	60.3 kg (13.0) r = 0.918	60.4 kg (13.2) r = 0.896
DXA	49.2% (6.4)	55.2 kg (9.4)	56.9 kg (9.6)

*%BF, FM and FFM: Mean (SD).
**Pearson r (p < 0.001) for very measurement.

their mean values are plotted for each body composition measurement (%BF, FM, FFM) according to the Bland-Altman method.[4]

Results

Of the patients, 75.8% were female with a mean age of 43.3 (10.6) years and a mean body mass index [BMI]

of 46.5 (5.34) kg/m². Table I shows the %BF, FM and FFM measurements obtained by each of the different methods used. Each method significantly correlated with DXA, although the Holtain BIA showed the worst correlation with DXA for %BF and FFM (table I). Nevertheless, the Bland Altman plots showed wide limits of agreement, as can be seen in figures 1 and 2, although 100 % of the data points for %BF laid within ± 1.96 SD of the mean difference for O300, O 500 and T, and 97.5% for H. T showed the most reliable results for %BF and FFM when compared to DXA, where the difference between the two methods was only -0.5% and + 1.5%, respectively (figure 1 and 2).

Discussion

Dual-energy X-ray absorptiometry (DXA) has been considered the gold standard for body composition measurements in obese people (Hind et al, 2011). Anthropometric methods are not reliable methods in obese patients and single frequency-bioelectrical impedance (SF-BIA) analysis, foot-to-foot impedance meters (FFI) and upper body fat analysers (UBFA) have also been reported to be inaccurate in subjects with a BMI > 34 kg/m².[2,3] Other methods such as spectroscopy, bioelectrical impedance vectorial analysis,
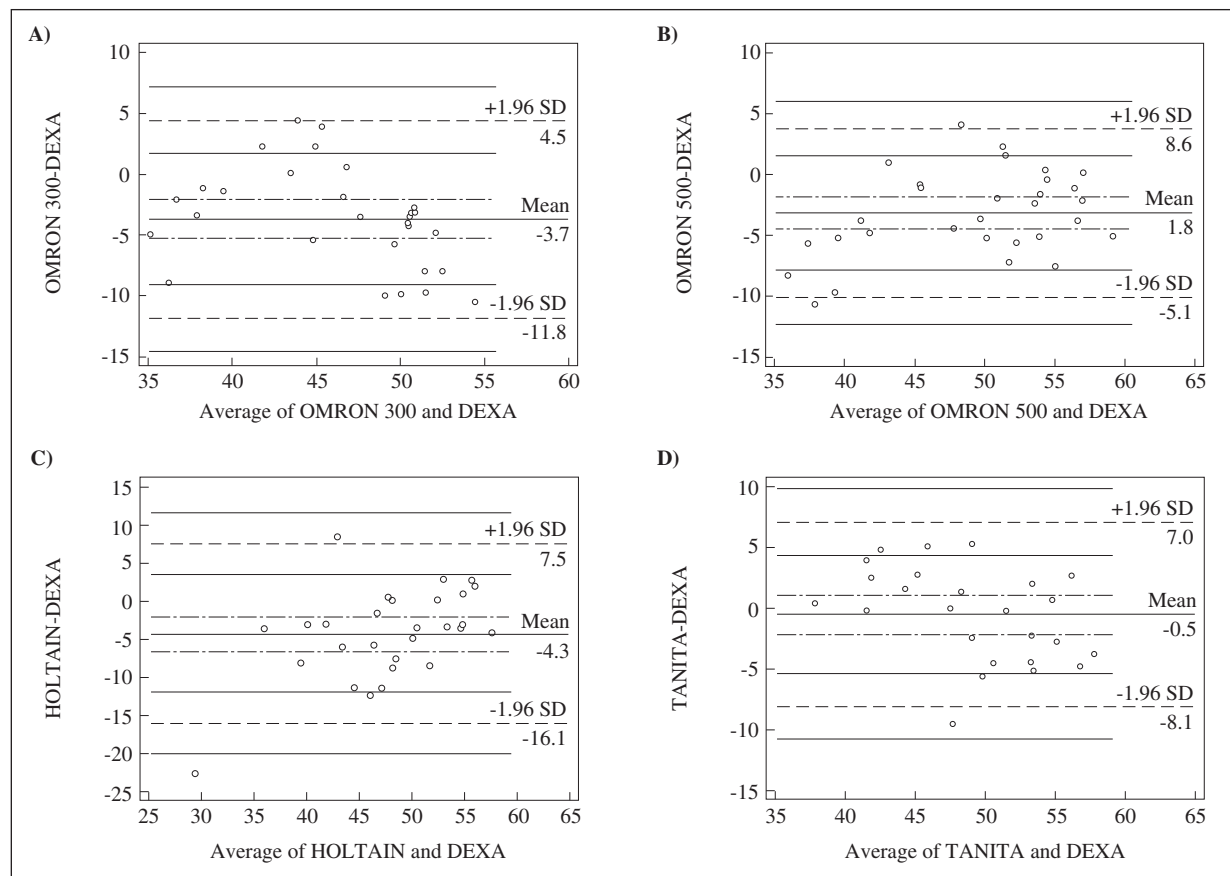

Fig. 1.—Bland Altman plot for the percentage of body fat (%BF) with OMRON BF 300 (1a), OMRON BF 500 (1b), HOLTAIN (1c) and TANITA (1d) compared to DXA.
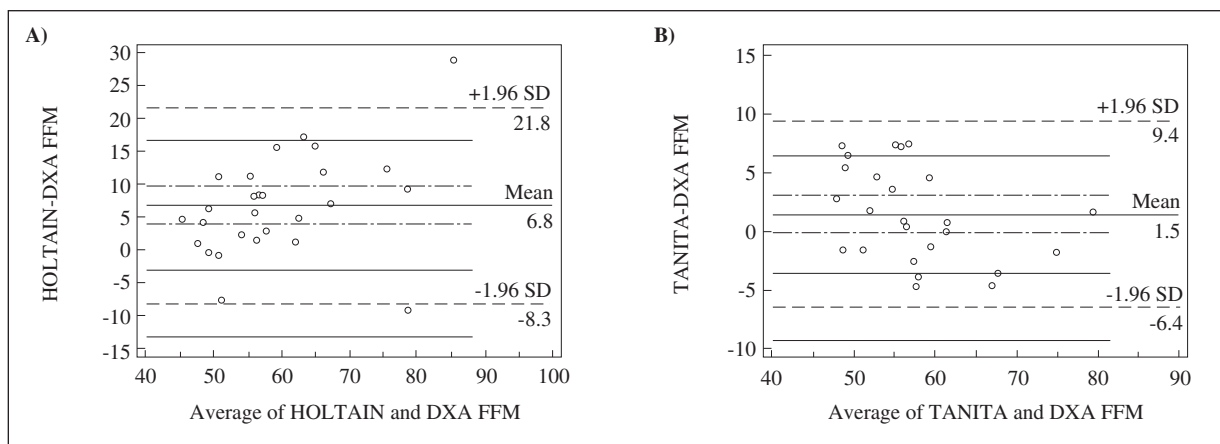
Fig. 2.—Bland-Altman plots for FFM with HOLTAIN (2a) and TANITA (2b) compared to DXA.

computerized tomography and magnetic resonance are most frequently used in investigational settings and are beyond the usual possibilities of a clinical unit. We attempted to validate the methods that are most commonly at hand in a clinical setting.

Our results showed quite a good correlation between the BIA methods and DXA, although considering the latter is the gold standard,[5] we found that the limits of agreement for each method were too wide. Similar results were previously reported, indicating that a good correlation between BIA and DXA is not always accompanied by reliable enough limits of agreement between methods.[6,7] This means that, as shown in figure 1 , the mean difference with DXA could be as large as -4.3% for Holtain, which clearly underestimates the %BF, but the range may be between -16.1 and + 7.5%, which is too wide from a clinical point of view and precludes the use of this method in obese patients. The range for the other three methods is narrower and more similar between the methods. The OMRON BF 500 was the only method that slightly overestimated both %BF and FM. The best results were obtained using TANITA TBF 300, which ranged from -8.1 to +7%, with a mean difference of -0.5%. As the OMRON BF 300 only measures hand-to-hand impedance and TANITA TBF 300 only measures foot-to-foot impedance, perhaps the differences are not just related to the method but also to the different segments of the body measured, as the highest percentage of body fat in obese people can be in either the upper or lower half of the body. We know that BIA is based on the assumption that the body is a cylindrical conductor with a uniform cross-sectional area, but this may not be true in obese patients.[8,9] Shafer et al.[10] reported that the underestimation of %BF in obese patients could be due to the estimation of trunk resistance by current segmental MF-BIA devices, requiring further examinations of the effect of body fat distribution on the accuracy of BIA measurements to be performed.

Moreover, severely obese patients may have altered electrical properties in tissues, which do allow complete penetration of the electrical current, resulting in inaccurate BIA measurements.[11] Obese people often have increased total body water contents and a high extracellular to intracellular water ratio, which could cause overestimation of FFM and an underestimation of FM.[7] This seems to be the case in our report, as most methods underestimated the %BF and FM, but the wide range of results found indicates that there could be some other factors causing this innacuracy. The lack of specific equations for obese people has also reported as a problem for the reliability of BIA in body composition assessments.[12] Bellido[13] studied 288 obese or overweight patients using the SF-BIA Tanita TBF 305 and applied a specific mathematical model derived from the impedance value obtained, which showed a lower bias than that of the model included with the method when compared to a DXA LUNAR model DPX-L. Although Volgyi et al.[14] reported a systematic underestimation of the percentage of FM, they also achieved a better accuracy using MF-BIA (Multi-Frequency Bioelectrical Impedance Analysis) compared to DXA after changes to the software.

In our study, we used SF-BIA as they are the devices most commonly found at hand in a normal clinical setting. MF-BIA includes impedances at multiple frequencies (0, 1, 5, 50, 100, 200 to 500 kHz) to evaluate FFM, TBW (total body water), ICW (intracellular water) and ECW (extracellular water). The MF-BIA method has been reported to be more accurate and less biased than SF-BIA by some authors[15,16] but not by others,[7] and it is more expensive and not so easily found in a clinical setting. In a recent report by the NUGENOB study,[17] strong correlations were also found for FM and FFM between MF-BIA and DXA (Lunar, r = 0.78 and r = 0.90, p < 0.001 for both), similar to those obtained in our study with SF-BIA and FFI/UBFA. However, again, FM was underestimated by BIA and the limits of agreement for FM (kg) were too wide (-10.11; 3.77), as shown by our results (figures 1 and 2). Other methods of assessment, such as bioelectrical impedance vector analysis (BIVA or

vector BIA) or bioelectrical spectroscopy (BIS) are even more difficult to obtain.

Other groups tested BIA and compared it to DXA. Lukaski and Siders[18] compared a Tanita TBF 604FFI and an Omron HBF 301 impedance meter with hand electrodes against a 50 kHz RJL medical-type impedance meter and a DXA Hologic QDR 2000-W (Hologic, Bedford, Massachusetts, USA). They reported that the Tanita TBF 604FFI obtained data that were closer to those of DXA than those of Omron, as found in our series. The Tanita TBF 604 underestimated %BF by 2.6 points in women and overestimated it by 1.2 points in men compared to DXA, whereas the HBF 301 underestimated it by 6.3 points in women and by 2.3 points in men. They attributed the higher accuracy of the FFI to the fact that plantar electrodes offer consistent and full contact with feet due to weight, whereas hand electrodes require voluntary squeezing of the grips. The same could be applied to our results.

Boneva et al.[19] performed a cross-sectional study including 159 women and 124 men who were subdivided according to sex and body mass index (BMI): BMI < 30 kg/m^{2} (66 women and 50 men); BMI 30-35 kg/m^{2} (53 women and 44 men) and BMI > 35 kg/m^{2} (40 women and 30 men). They tested a Tanita TBF-215 FFI analyser against a DXA Hologic QDR 4500. As found in our series, DXA and BIA were highly correlated but the correlations decreased with increasing BMI. The limits of agreement were much better in men than in women and increased with increasing BMI in both sexes. The small number of male patients in our series did not allow us to study this possible gender difference. They explained the divergence of BIA and DXA measurements at a BMI > 35 kg/m^{2} through different factors: the higher percentage of FFM hydration in obese patients, the increased extracellular space in adipose tissue, and the fact that obese people have more fat in muscle and around organs, which is seen as lean body mass by BIA.

In conclusion, measuring body composition in severely obese patients in a clinical setting is not an easy task. Compared with DXA, FFI and UBFA could be useful for assessing the body composition of severely obese people, although it must be taken into account that they appear to underestimate %BF and FM and their limits of agreement are too wide.

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