Bioimpedance for Severe Obesity: Comparing Research Methods for Total Body Water and Resting Energy Expenditure

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Objective: As the acceptance of surgical procedures for weight loss in morbid obesity is increasing, clinically useful baseline and follow-up measures of total body water (TBW) and resting energy expenditure (REE) are important. Research methods such as deuterium (D^2O) dilution and metabolic carts are problematic in the clinical setting. We compared bioimpedance analysis (BIA) predicted (Tanita TBF-310) and measured TBW and REE.
Methods and Procedures: Forty-two paired presurgery studies were completed using BIA and D^2O in patients with BMI (mean ± s.d.) 50.2 ± 8.8 kg/m^2 for TBW, and 30 patients with BMI 51.0 ± 13 kg/m^2 completed paired determinations of REE with metabolic carts and the Tanita balance with weight, height, sex, and age modifiers. Regression analysis and Bland–Altman plots were applied.
Results: When regression analysis was completed for TBW, regression line was consistent with the identity line "$y = x$." The intercept was not different from 0 (95% confidence interval −2.5 ± 7.0). The slope of the line was not different from 1.0 ± 0.1. The measured TBW 51.2 ± 10.1 l had a correlation with the predicted 49.5 ± 11.27 l of 0.92. There also was no significant difference ($P = 0.33$) between predicted (2,316 ± 559 kcal/day) and measured REE (2,383 ± 576 kcal/day); δ 66.7 ± 273 kcal/day. The two measures were highly correlated ($r = 0.88$) with no bias detected.
Discussion: These observations support the use of the BIA system calibration in subjects with severe obesity. Without the use of complex, costly equipment and invasive procedures, BIA measurements can easily be obtained in clinical practice to monitor patient responses to treatment.

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INTRODUCTION

The prevalence of obesity is increasing worldwide and with it the associated comorbidities that affect the patient's quality of life and consume health-care dollars (1–9). There currently is an intensive effort by governments and all those concerned with public health to stop this increase in body size which is producing a negative effect on nations and their populations (10–14). New efforts at dietary approaches, medications, and surgery are being invoked (15–18). To test the efficacy of these new strategies, accurate and precise measures of weight and body composition are required. Such instrumentation would ideally be affordable and user-friendly; however, proven research methods are not available for most clinical practices. Earlier we had compared the Tanita 310 body composition measurements with four other clinical and research methods for determining body composition including under water weighing. All five methods for obtaining body composition measurements were completed on the same individual during a single research visit (19). As the Tanita 310 total body water (TBW) compared favorably with the "gold standard" underwater weighing, we began an evaluation of the Tanita 310 in a morbidly obese population requesting weight loss surgery at the Surgical Weight Loss Clinic of Mt. Sinai Medical Center. All patients requesting surgery had their body composition measured by the foot-to-foot bioimpedance (BI) methodology of the Tanita 310. However, there is disagreement in the literature that this methodology is accurate for larger people (20–27). In 1996, Deurenberg thoughtfully discussed the limitations of BI analysis (BIA) in morbid obesity (20). All the reasons of tissue hydration and distribution and body fat distribution in morbid obesity could impose measurement errors. Challenged to follow the weight loss process after bariatric surgery in the

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clinical setting, we obtained research support and began this study of body composition change with the Tanita 310 in comparison with the deuterium-dilution research procedure completed at the same research visit. At an earlier time, we had begun data collection for a comparative study of the calculated resting energy expenditure (REE) from the Tanita 310, which basically uses a modified Harris–Benedict equation with gender, age, weight, and height variables with a measured REE obtained with a Deltatrac 2 metabolic cart. The aim of these projects was to evaluate whether this user-friendly and affordable equipment would provide comparable data to the more standard, labor-intensive, and costly procedures of weight loss research. If so, studies of morbidly obese bariatric surgery patients would be greatly facilitated.

METHODS AND PROCEDURES

After an initial consultation requesting a weight loss procedure, if patients were granted permission to proceed with their evaluation, they were approached to participate in this research protocol and sign an informed consent approved by the Mt Sinai School of Medicine Institutional Review Board. A total of 127 patients who met the National Institutes of Health criteria for weight loss surgery were approached according to recruitment staff availability over an 8-month period. Those who were excluded from participation because they were not able to commit to biweekly visits and additional time required by another part of the protocol were asked to serve as controls for that section of the protocol regarding weight change before surgery (28). Patients in excess of 600 lb were excluded because Tanita and metabolic cart measurements were not possible.

At a research visit, patients had their REE estimated using a Deltatrac 2 metabolic cart (SensorMedics, Yorba Linda, CA).

Following the standard guidelines most recently reviewed by Compher and the evidence analysis working group of the American Dietetic Association, all participants were requested not to have eaten after midnight (26). They rested 20 min at a comfortable room temperature of 20–25 °C before a 15-min measurement. The machine was calibrated before each measurement. A steady state was indicated by <10% variation in oxygen consumption and carbon dioxide production. The initial 5 min of measurement were discarded. The Deltatrac 2 reliability or test–retest of 4% is within the physiologic variation of REE on a day-to-day basis.

The Tanita 310 uses BI methodology to predict body water and calculate REE by formula based on the Harris–Benedict equation (27). Patients stand with their bare feet on a platform while an imperceptible electric current passes from foot to foot. The resistance measures impedance with the measured weight, height, gender, and age together to predict the body water. A second group of patients who had agreed to participate in a weight loss protocol before surgery had Tanita 310 body composition measurements and then had a fasting blood drawn. Patients drank labeled water (D^2O) at about 0.1 g per kg of body weight and waited for a 3-h period to allow for complete mixing before obtaining the final blood. Blood samples were centrifuged, separated, and plasma samples were sent to the body composition unit of the Obesity Research Center, St.Luke's-Roosevelt hospital for D^2O dilution analysis (29). The reliability for tracer dilution studies is ± 1 l.

Statistical methods

Regression analysis and paired "*t*" tests were performed to examine the correlation and statistical significance of mean paired differences observed for body water determinations from the Tanita and D^2O dilution studies and the Deltatrac 2 measured and calculated REE from the Tanita with the Harris–Benedict equation. Bland–Altman plots, which assess the agreement between two clinical measurements, were completed to compare the Tanita 310 determinations with the accepted research methods (30). All results are expressed as means ± standard deviations. For all differences, a *P* value of 0.05 was considered statistically significant.

RESULTS

Forty-two studies (35% men and 65% women) were completed during the same research visit using the Tanita 310 and D^2O to measure TBW. The mean age was 42.4 ± 8.1 with a mean BMI 50.2 ± 8.8 kg/m^2 for TBW studies (**Table 1**). Thirty patients with BMI 51.0 ± 13 kg/m^2, mean age of 41.8 ± 9.9, completed measurements of REE with a metabolic cart and the Tanita 310 calculations with gender, weight, height, and age modifiers. Two surgically reduced patients contributed to the REE database. Five of the patients who had measurements of REE also participated in the TBW studies. Of the consented patients there were no drop outs before the completion of the duplicate measurements.

When regression analysis was completed for TBW, the fitted regression line was consistent with the identity line "$y = x$." The intercept was not different from 0 (95% confidence interval −2.5 ± 7.0). The slope of the line was not different from 1 (1.0 ± 0.1). The measured TBW 51.2 ± 10.1 l had a correlation with the predicted 49.5 ± 11.27 l of 0.92 (**Figure 1**). The intraclass correlation coefficient was 0.91 (95% confidence interval + 0.82–0.95). The Bland–Altman plot provides a comparison of the differences of the measured versus predicted TBW with the averaged values of the determinations (**Figure 2**). There also was no significant difference (P = 0.33) between Tanita predicted (2,316 ± 559 kcal/day) and measured REE (2,383 kcal/day ± 576); δ 66.7 ± 273 kcal/day (**Figure 3**). The two measures were highly correlated (r =0.88) with no bias detected. The intraclass correlation coefficient was 0.88 (95% confidence

Table 1 Demographics

	Subjects	Gender	Age	BMI Mean ± s.d.	BMI Range
TBW	42	27 female (65%) 15 male (35%)	42.4 ± 8.1	50.2 ± 8.8	(37.9–78.2)
REE	30	20 female (67%) 10 male (33%)	41.8 ± 9.9	51.0 ± 13	(27.8–76.2)

REE, resting energy expenditure; TBW, total body water.

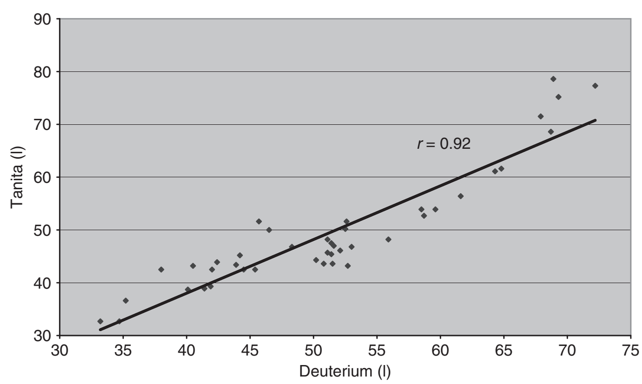

Figure 1 Total body water comparison of D^2O and Tanita 310.

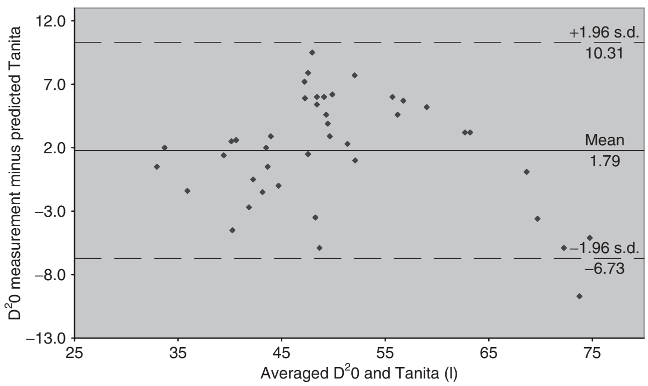

Figure 2 Bland–Altman plot comparing measured and predicted total body water.

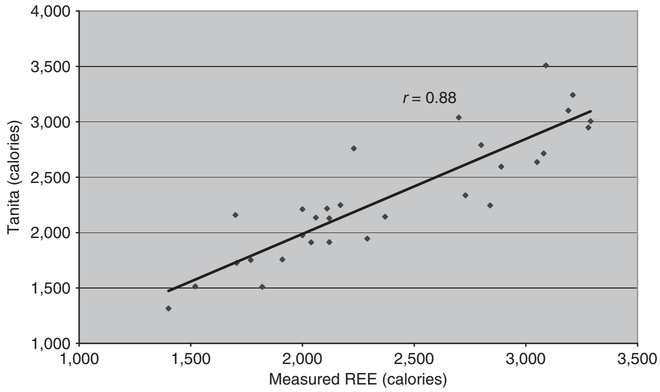

Figure 3 A comparison of measured resting energy expenditure (REE) compared with Tanita 310 predicted.

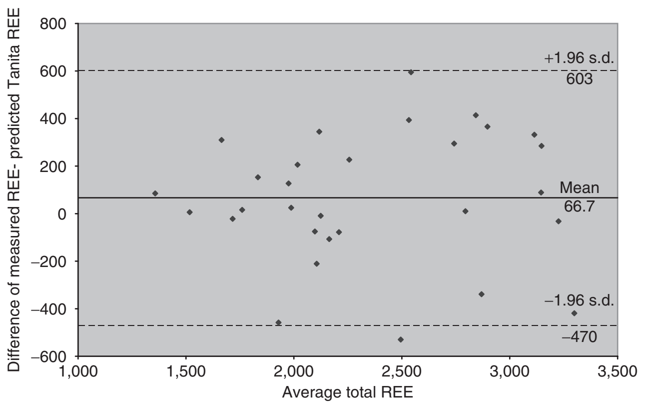

Figure 4 Bland–Altman plot of differences in measured and predicted resting energy expenditure (REE).

interval 0.77–0.94). The Bland–Altman plot of the differences between the two methods for the individual studies shows the agreement of the metabolic cart and the Tanita calculation (**Figure 4**).

DISCUSSION

The population reported here is unique to the body composition literature because participants are candidates of weight loss surgery and classified as morbidly obese. In fact the mean BMI of the subjects is 50 which places the group in the super obese category. Because our observations demonstrate such high agreement for the Tanita 310 using BI methodology with research isotope dilution, one might question why such divergent results are reported in the literature for the morbidly obese. Pateyjohns and coworkers recently compared three different instruments for BIA of body composition with dual-energy X-ray absorptiometry measurements in a population of men with BMIs 28–43 and reported differences in the accuracy of the three methods (25). Such studies provide data that contribute to an understanding of the divergent reports that exist. It is also of importance to note that dual-energy X-ray absorptiometry has size limitations of the equipment. Research efforts are in progress to modify the technical approach to expand the size limitations to study larger people. Methodology is continually being revised to facilitate measurement and data collection particularly in larger patients where such information is important to providing appropriate clinical care. The Tanita 310 which has been modified to measure body water in individuals weighing up to 600 lb serves as a useful tool for assessing body fat change in larger individuals who have bariatric surgical procedures for that purpose. In these individuals, accuracy certainly is difficult to access and fluid shift plagues evaluation; however, with the high correlation with isotopic methods which are very time consuming and require analytic expertise, the Tanita 310 appears to be a clinically useful tool.

The Bland–Altman plot of the body water analysis pointed up one outlier. This patient differed from others in that he had directly lost 21 lb before his body water evaluation. At intake he had a BMI of 60.5 and was taking no medications. He was a relatively young man, aged 39 years, and the Tanita 310 calculation of body fat was 47%. The divergent body water results obtained by the two methods remain open to conjecture.

The nutrition literature is replete with various predictive equations for the determination of REE metabolic rate in comparison with measured REE (31). The Harris–Benedict has been criticized for inadequate sampling size and systematic error particularly in larger people; nevertheless, it remains the most frequently used metabolic standard equation. Multiple validation studies have been completed. In contrast to many reports and criticisms in the literature, the morbidly obese patients here reported demonstrated measured REE that highly correlated (r = 0.88) with the rates calculated by the Tanita using the Harris–Benedict equation. This is in agreement with the observations of Das and coworkers that support the standard equations for the nonobese population providing the most accurate estimates of REE compared with equations adjusted for body weight (32). The population of Das and coworkers strongly resembles our population in mean BMI although all were woman. For the morbidly obese population, REE was not accurately predicted by the numerous equations developed for obese populations. Again, the clinical usefulness of the metabolic information requiring little professional input and effort speaks strongly as an assist to both the clinician and the researcher.

These observations support the use of the BIA system calibration (Tanita 310) in subjects with severe obesity. Without the use of complex, costly equipment and invasive procedures, Tanita 310 measurements of body water can easily be obtained with sufficient accuracy in the clinical setting to monitor patient responses to treatment. The calculations of resting metabolic rate based on the data programmed into the Tanita 310 computer offer additional information without additional effort to assist in patient management and care.

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DISCLOSURE
The authors declared no conflict of interest.

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