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ANALYSIS OF BODY COMPOSITION USING BIOIMPEDANCE (BIA) DATA

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ABSTRACT

BACKGROUND: Knowledge of body composition in health and disease has been a continuing interest for clinicians, because components of the body often provide more useful information than the whole-body measurements of weight, height, and the derived parameter, body mass index. Bioelectrical impedance analysis (BIA) is a widely used method to estimate body composition. The technology is relatively simple, quick, and noninvasive. The porpose of this study was to determine the body composition changes of 11-days clinic-based weight management program. SUBJECTS AND METHODS: For a period of two years (2004-2005) we studied 519 overweight and obese women (BMI, X ±SD, 32,94 ±6,51 kg/m^2). The diagnostic protocol included antropometric data, body composition analyse with Tanita ® leg-to-leg BIA system (model TBF – 300A), blood analysis, cardiological, dietological and physiotherapeutical specialist consult. All of patients keep to a low-calory diet, intensive everyday exercise and physioterapy procedures. The lectures course included of basis nutrition, healthy eathing, long-term exercise programm. RESULTS: Weight loss for the group was 2.57 kg. The fat-mass loss was 1.25 kg, free-fat mass was also decrease 1.31 kg. Reductions in circumferenses of waist and hip for the group was 3.9 cm and 3.09 cm respectively. Basal metabolic rate was significantly reduced ($p < 0.001$). Patients had improved some components (total cholesterol, HDL cholesterol, fasting glucose, blood pressure). CONCLUSION: These results support the field use of BIA for estimating changes in fat mass as it is simple to use, requires minimal training and is used across a spectrum of ages, body weights, and disease states.

Keywords: bioelectrical impedance analysis, body composition, fat mass

Bioelectrical impedance analysis (BIA) was developed in the 1960s and has emerged as one of the most popular methods for estimating relative body fat [1–3]. BIA is relatively simple, quick, portable and noninvasive and is currently used in diverse settings, including private clinicians' offices, wellness centers and hospitals [4]. The technology actually determines the electrical impedance of body tissues, which provides an estimate of total body water (TBW). Using these values of TBW derived from BIA, fat-free mass (FFM) and body fat may then be estimated. BIA measures the opposition of body tissues to the flow of a small (less than 1 mA) alternating current. Impedance is a function of two components (vectors): the resistance of the tissues themselves, and the additional opposition (reactance) due to the capacitance of membranes, tissue interfaces, and nonionic tissues [5].

The standard error of estimate (SEE) or prediction error for BIA is about 3.5% [3]. There is still debate over whether or not BIA accurately predicts changes in body composition during a weight loss program [6]. Published studies are mixed, with some supporting the accuracy of BIA in detecting FFM and body composition changes [7–9], while others claim there is substantial over- or under-estimation when compared to the underwater weighing method [10–15]. Standardization of the procedures used to obtain BIA measurements is essential to provide meaningful estimates of TBW or fatness. In principle, BIA would appear to have many advantages in collecting these body composition parameters. Measurement of impedance is precise, consistent, easy to obtain, portable, and relatively inexpensive [5].

Single frequency BIA (SF-BIA), generally at 50 kHz, is passed between surface electrodes placed on foot-to-foot, hand-to-hand or hand-to-foot electrodes [16, 17]. Nucez et al [18] evaluated a single-frequency 50-kHz leg-to-leg BIA system combined with a digital scale that uses stainless steel pressure-contact foot pad electrodes. This leg-to-leg BIA system is functionally different from other BIA systems, which require the use of arm and leg electrodes and separate measurement of body weight. Data from Nucez et al [18] indicated that pressure-contact electrodes provided impedance measurements and body-composition stimates that were comparable with those obtained with use of conventional gel electrodes, and offered the advantage of increased speed and ease of measurement.

In most studies evaluating the use of BIA in monitoring changes in the body composition of obese subjects, subject numbers were small, very-low-energy diets were used, and changes in fat-free mass were below the SEE of the BIA

method [10–14, 19-23]. In no studies were subjects randomly assigned to moderate energy restriction, exercise and physiotherapeutical procedures as is typical in multicomponent clinic-based weight-management programs.
This study had 2 objectives: to determine the validity of the leg-to-leg BIA system in *1*) estimating body composition in obese and overweight man and women and *2*) assessing changes in body composition in these patients after 2 wk multicomponent clinic-based weight-management programs.
In addition, standardized testing procedures must be followed. Although the relative redictive accuracy of the BIA method is similar to that of the skinfold method, BIA may be preferable for the following reasons: (a) the method does not require a high degree of technical skill, (b) the method is more comfortable and less intrusive for the client, and (c) this method can be used to estimate body composition of obese individuals (31). Recently, less expensive, segmental bioimpedance analyzers have been marketed. The Tanita® analyzer measures lower-body resistance between the right and left legs as the individual stands on the electrode plates of the analyzer

MATERIALS AND METHODS

Subjects and Research Design

Overweight and obese women (n = 519) with no overt disease were take part of weight management program. Subjects were recruited according to these selection criteria obtained from a pre-study medical history questionnaire: 1) in good health and with no known diseases including cancer, diabetes and coronary heart disease, 2) pre-menopausal women, 3) a body mass index (BMI) between 25 and 55 kg/m2, 5) not currently on a weight loss diet and weight stable within 5% of body weight over the past year, 6) less than 30 minutes of moderate-to-vigorous exercise a day and 7) not experiencing any pain that would interfere with full participation.
All subjects were prescribed an energy-restriction diet, exercise program and physiotherapeutical procedures for 2 weeks, with body composition and nutrient intake measured pre-study and after week 2.

Laboratory Procedures

After an overnight fast, subjects came from hotel to the laboratory (~ 200m) at 8,30 AM. For determination of blood parameters, blood was drawn via an antecubital vein into a serum tube or in a tube filled with EDTA. Laboratory parameters: hemoglobin, blood glucose levels, total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, were determined in a certified laboratory using standard methods.

Anthropometry

Height and weight was obtained using a mobile combinat stadiometer-digital balance (model 225; Seca, Hamburg, Germany). Fat distribution was investigated by measuring the waist and hip circumference and calculating the waist to hip ratio (WHR).
The waist circumference was measured at the smallest circumference between the rib cage and the iliac crest with the subject standing. The hip circumference was measured at the widest circumference between the waist and the thighs. The WHR was calculated by dividing the waist circumference by the hip circumference.

Body composition

In the first day of the weight management program, and the last week of the 2-wk study, the body composition of all obese subjects were assessed. In order to ensure the predictive accuracy of these equations, clients must strictly follow each of the BIA Testing Guidelines. Before testing, subjects were required to adhere to these BIA testing guidelines (3): 1) to not eat or drink within 4 h of the test, 2) to maintain normal body hydration, 3) to not consume caffeine or alcohol within 12 h of the test, 4) to not exercise within 12 h of the test, 5) to not take diuretics within 7 d of the test, 6) to urinate within 30 min of the test, and 7) No testing of female clients who perceive they are retaining water during that stage of their menstrual cycle [24].
BIA measurements were taken by using the Tanita ® leg-to-leg BIA system (model TBF – 300A). The Tanita® analyzer measures lower-body resistance between the right and left legs as the individual stands on the electrode plates of the analyzer. Subjects were measured while standing erect, in bare feet, on the analyzer's footpads and wearing either a swimsuit or undergarments. The system's 2 electrodes are in the form of stainless steel foot pads. Leg-to-leg impedance and body mass are simultaneously measured as the subject's bare feet make pressure contact with the electrodes and digital scale.
The body fat monitor/analyzer automatically measures weight and then impedance. Computer software (a microprocessor) imbeded in the product uses the measured impedance, the subject's gender, height, fitness level, and in some cases age, (which have been preprogrammed), and the weight to determine body fat percentage based on equation formulas. Through multiple regression analysis, Tanita has derived standart formulas to determine body fat persentage. Tanita's equations are generaluzed for standard adults and athletes.

Specialist consultation

Cardiological consultation. The nurse make the standart cardiogram and after that, patient visit the cardiologist. Cardiologist examine cardiovascular fitness, blood pressure, puls, give an interpretation to cardiogram. Seated blood pressure was measured in duplicate after 10 minutes of rest, 2 to 3 minutes apart. If the readings differed by 4 mm Hg or higher, then a third reading was taken. Extreme blood pressures were confirmed on a subsequent visit.
Physiotherapy consultation. Physiotherapist examine the health status, especially condition of the articulations, joints pain and movement, also skin status and other diseases. Specialist determine the contraindication for physiotherapy and prescribe some

physical procedures, like anticellulitis massage, termotherapy, electrotherapy, underwater massage, ets.

Dietology consultation. All of patients have the conversation with dietologist. Specialist determine the daily feeding, nutrition status, basal metabolic rate and give the recommendation for diet at home. Dietologist have a talk with group above the basis of nutrition and dietetics.

Energy-Restriction Diet

Each subject's basal metabolic rate (BMR) was estimated automaticaly using the Tanita ® leg-to-leg BIA system (model TBF – 300A). Obese subjects were prescribed a 1000–1200 kcal/d diet for 2 wk. The dietary menu was based on National dietary recommendations (Bulgaria). The goal of the intervention was a weight loss of 0.5–1.0 kg/week. Caloric intake was restricted using a balanced diet (~ 50% carbohydrates, ~ 30% protein, 20–60 g fat/day). A minimum volume intake of at least 2 l was suggested using 1,5 l mineral water or 0,5 l herbal tea with soft diuretic and laxative effect as beverage. Intentional weight loss was controlled by weight control and by bioelectric impedance analysis at indicated times. Caloric intake restriction was supported by a behavioural program, which consisted of group sessions.

Training program

In addition to weight management program, patients underwent a regular training program, which was performed every day per week at a level of 60–80% of their initial heart rate reserve. The patients arranges in 2 training groups according to intensity and difficulty of exercise. The exercise routine consisted of 20 min of morning gymnastics, 30 min complex of curative aerobic gimnastic, 60 – 90 min outdoor walking or jogging (terenkur), aqua-aerobic exercises in swimming pool with mineral water (25 min), individual analytic training (up to 60 min), cycle ergometry (60 W, up to 30 min) and dance teaching (up to 120 min). Patients wore the pedometer (Tanita ®) every day of study and daily distance was recorded in an exercise log. A trained exercise physiologist supervised all exercise sessions, and performed random checks of heart rate. Each exercise session was supervised to ensure correct technique and to monitor the appropriate amount of exercise and rest intervals. No injuries or complications were reported from the exercise testing and training program.

Physiotherapy program

All of patint's are prescription for some procedures after the physiotherapy consultation and assessment of health status. Everyday are followed procedures: manual massage of the targeted zones with anticellulitic cream (15 min.), underwater massage (20 min.), electrotherapy procedure (30 to 45 min.), phytotherapy – tea with appetite-depressing and light diuretic effect.

Behavior modification

The behavioral component of the intervention was based on the principles and processes of the National Recommendation For Healty Lifestyle (Bulgaria). Motivational and behavioral principles to modify eating patterns, to initiate and/or continue moderate exercise and to increase the activities of daily living were introduced. Several daily educational classes (e.g., emotional eating, stress management, mood management, time management, maintaining behavioral changes), and optional support groups and individual therapy were provided.

RESULTS

Subjects complying with all aspects of the study design included 519 overweight and obese women. Baseline characteristics of subjects enrolled in the trial are shown in Table №1. Table №1 present the mean value, standart deviation and range of values in pre-intervention study.

Table №. Subject characteristics (n = 519)

Subject Characteristics	Mean ±SD	Range
Age (years)	42.66 ±10.87	22 - 62
Height (m)	162.20 ±5.81	147 - 173
Weight (kg)	86,74 ±17,46	58,00 - 140.8
Body mass index (kg/m2)	32,94 ±6,51	25,10 - 54,90
BMR (kcal)	1565,15 ±187,78	1244 - 2151
BMR (kJ)	6520,72 ±670,55	5249 - 8001
Impedance (ohms)	505 ±66	345 - 750
Fat mass (%)	41,25 ±4,86	31,30 - 51,50
Fat mass (kg)	36,47 ±11,33	19,40 - 70.5
Fat-free mass (kg)	50,25 ±6,83	38,6 - 77
Waist circumference (cm)	94,28 ±12,56	77 - 129
Hip circumference (cm)	116,33 ±11,94	98 - 156
WHT	0,81 ±0,06	0,64 - 0,95

Table 2. Weight and antropometric changes from baseline to post-intervention in a study group (n = 519).

Subject Characteristics	Baseline (SD)	Post (SD)	Difference
Weight (kg)	86,74 (17,46)	84,18 (16,73)	- 2,57
Body mass index (kg/m2)	32,94 (6,51)	31,93 (6,30)	- 1,00
Waist circumference (cm)	94,28 (12,56)	90,38 (12,83)	- 3,90
Hip circumference (cm)	116,33 (11,94)	113,23 (11,74)	- 3,09
Waist-to-hip ratio	0,81 (0,06)	0,79 (0,14)	- 0,02

Weight and antropometric changes was significantly decrease, weight loss was 2.57 kg (3% of total average group weight for 2 wk).

The results of body composition change are presented in Table №3. Mean body mass decrease was 2.57 kg with free fat mass accounting for about 51% of this change. This is adequat result after the first 2 wk of intensive weight reduction program, because a main loss is total water in the body 0.96 kg (73% of reduced free fat mass). The content of fat mass is reduced with 1.25 kg on the average (49% of the reduced tissues). In the end of intervention basal metabolic rate was decrease.

Table 3. Body composition changes from baseline to post-intervention in a study group using the Tanita® analyzer (n = 519).

Subject Characteristics	Baseline	Post	Difference
Fat mass (%)	41,25 (4,86)	41,06 (5,19)	- 0,19
Fat mass (kg)	36,47 (6,83)	35,22 (11,48)	- 1,25
Fat-free mass (kg)	50,25 (6,83)	48,94 (5,84)	- 1,31
Total body water (kg)	36,78 (5,00)	35,82 (4,28)	- 0,96
BMR (kcal)	1565,15(187,78)	1547,37 (176,57)	- 17,79
BMR (kJ)	6520,72 (670,55)	6459,64 (661,73)	- 61,09

CONCLUSION

These results support the field use of BIA for estimating changes in fat mass as it is simple to use, requires minimal training and is used across a spectrum of ages, body weights, and disease states.

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