RESEARCH ARTICLE

Bioelectrical Impedance Analysis and its Interpretation

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Manuscript Details

Received : 15 May, 2014
Revised : 07 June, 2014
Re-Revised : 08 July, 2014
Revised received: 17 September, 2014
Accepted: 27 September, 2014
Published: 02 October, 2014

ISSN: 2322-0015

Cite this article as: Gupta Swaroopa Rani N. Bioelectrical Impedance Analysis and its Interpretation, *Int. Res. J. of Sci. & Engg.*, 2014; 2 (5):171-176.

ABSTRACT

For ideal weight management and for a more accurate and precise body composition analysis full Body Sensing Technology Karada Scan Body Composition Monitor – HBF-375 is used which measures body composition- weight, body fat percentage, visceral fat level, subcutaneous fat and skeletal muscle percentage, RM, BMI and Body age. This analysis technique is based on Bioelectrical impedance method. The general principle behind BIA is that two or more conductors are attached to a person's body and a small electric current is sent through the body. The resistance between the conductors will provide a measure of body fat between a pair of electrodes, since the resistance to electricity varies between adipose, muscular and skeletal tissue. Fat-free mass (muscle) is a good conductor as it contains a large amount of water (approximately 73%) and electrolytes, while fat is anhydrous and a poor conductor of electric current. Each (bare) foot may be placed on an electrode, with the current sent up one leg, across the abdomen and down the other leg.

Key Words : Body age, Body fat, BMI, RM, Skeletal muscle, Subcutaneous fat, Visceral fat.

INTRODUCTION

Bioelectrical Impedance analysis was used to establish their Nutritional Status. One hundred participants as in (Patterson and Shanholtzer, 2002) where measured using bioelectrical impedance analysis to assess the accuracy of total body water (TBW), extracellular water (ECW), and intracellular water (ICW). France *et al*. (2005) reported Thirty-two volunteer's hydration status was measured using bioelectrical impedance analysis to monitor fluid shifts and cardiovascular function. Forty subjects were measured as in (Patterson and Spinks, 2005) using bioelectrical impedance analysis to assess their Total body water (TBW), intracellular body water (ICW), extracellular body water (ECW), this was then taken with blood pressure readings to assess if there is a correlation. As in (Farman *et al*., 2002) Two hundred and thirty seven adults were measured using bioelectrical impedance analysis to establish their body composition including their lean and fat mass in comparison to Echocardiographic Image Quality. Bahadori *et al*. (2003) studied one hundred and twenty subjects were recruited for this project, forty four of whom were obese. Bioelectrical impedance was used to measure the cohorts progress on the diet and effects on the lean body mass.

Baker *et al*. (2005) studied twenty seven patients to see if Lean body mass, calculated by bioelectrical impedance analysis, could be used to more accurately drug dose in obese cardiac patients. As in (Maughan *et al*., 2005) measured the body fat of twenty eight subjects and compared different methods of body composition analysis for accuracy. Study (Fuller *et al*., 1993) is a comparison of various different bioelectrical impedance devices and formulas. Clewlow *et al*. (1998) twelve males subjects were used in their research project were bioelectrical impedance analysis was used to assess the effects of positive end-expiratory pressure on transthoracic impedance-implications for defibrillation. Durnin *et al*. (1994) thirty five elderly subjects were tested using bioelectrical impedance analysis to evaluate the use of equations on this population group. As in (El Habbal *et al*., 2005) ten jaundice babies body water was tested using bioelectrical impedance analysis to assess if this is reduced in this patient population. Paper (Bolton *et al*., 1998) looked at the feasibility on ten critically ill patients, of using bioelectrical impedance to monitor fluid shifts. Francaux and Poortmans (1999) twenty five male volunteers were measured using bioelectrical impedance to assess their intra cellular, extra cellular and total body water to show the effect of creatine on body composition. As in (Demeure *et al*., 2000) Bioelectrical Impedance was used to measure fourteen male subjects body composition pre and post exercise. In one of the pilot study (2001) Twelve volunteers were measured using bioelectrical impedance analysis to monitor the effectiveness of Slenernight supplements on their body composition. The aim of study (Barton *et al*., 2002) was to establish the effectiveness of Bioelectrical Impedance Analysis when measuring body composition in eighty five COPD patients. Guisado *et al*. (2003) by looking at the past history of patients aims to understand if this has any long term consequences on their body composition using Bioelectrical Impedance. This study used one hundred and four patients. Goran *et al*. (1997) studied Bioelectrical Impedance Measurements at Various Frequencies to Estimate Human Body Compositions. Patterson and Shanholtzer, 2003) the research, monitoring one hundred subjects, looked at how effective bioelectrical impedance is as a tool for psychophysiology research. As in (Harris *et al*., 2003) forty subjects were tested using bioelectrical impedance analysis to assess the lean mass in COPD patients. Research based of a mixed cohort of one hundred and sixty subjects (Ghosh *et al*., 1997). Of these roughly half were teenagers and half adults. This sample also included a proportion of patients with various medical disorders. The paper examines and compares Body stat's handheld Bioelectrical Impedance devices against the Dual Energy X-ray Absorptiometry Device (DEXA). The purpose of this paper is to establish whether or not hand-held Bioelectrical Impedance Analysis can be used accurately to establish body composition accurately and in a timely fashion. Elia *et al*, (1994) applied a three-component model of body composition to a group of obese women. Using 29 surgical patients the research project (Hannan *et al*., 1995) aimed to establish the best method for calculating extracellular water and total body water. The study (Cowen *et al*., 1998) eighty nine subjects a mixed of healthy, and patients with GI malignancies, chronic liver disease and IBD.

In present analysis of body composition such as Body Weight, BMI, Body Fat Percentage, Segmental Subcutaneous Fat & Skeletal Muscle Percentage (Whole Body, Trunk, Legs and Arms), Resting Metabolism, Visceral Fat Level and Body Age is done by Bioelectrical impedance technique and results are interpreted and corresponding instructions for better health improvement is given.

MATERIALS AND METHODS

For ideal weight management and for a more accurate and precise body composition analysis full Body Sensing Technology Karada Scan Body Composition Monitor – HBF-375 is used which measures body composition- weight, body fat percentage, visceral fat level, subcutaneous fat and skeletal muscle percentage, RM, BMI and Body age. The general principle behind Bioelectrical impedance analysis is that two or more conductors are attached to a person's body and a small electric current is sent through the body. The resistance between the conductors will provide a measure of body fat between a pair of electrodes, since the resistance to electricity varies between adipose, muscular and skeletal tissue. Fat-free mass (muscle) is a good conductor as it contains a large amount of water (approximately 73%) and electrolytes, while fat is anhydrous and a poor conductor of electric current. Each (bare) foot may be placed on an electrode, with the current sent up one leg, across the abdomen and down the other leg. There is little scope for technician error as such, but factors such as eating, drinking and exercising must be controlled since hydration level is an important source of error in determining the flow of the electric current to estimate body fat. The instructions for use of instruments typically recommended not making measurements soon after drinking or eating or exercising, or when dehydrated. Instruments require details such as sex and age to be entered, and use formulae taking these into account; for example, men and women store fat differently around the abdomen and thigh region.

BMI and Ideal weight: Body mass index is defined as the individual's body mass divided by the square of his or her height. The formulae universally used in medicine produce a unit of measure of kg/m^2.

BMI = Weight (Kg) / [height (m)] ^{2}

The WHO regards a BMI of less than 18.5 as underweight and may indicate malnutrition, an eating disorder, or other health problems, while a BMI greater than 25 is considered overweight and above 30 is considered obese.

The ideal BMI is 22. Maintaining an ideal weight can help prevent obesity or weight loss and other diseases, and lead a longer life. The ideal weight for BMI of 22 is calculated as follows.

Ideal Weight (Kg) = 22 × [height (m)] ^{2}

However this method of ideal weight calculation may not be applicable for professional athletes and body builders, who have higher muscles ratio in their bodies.

Body fat percentage:

Body fat percentage = [Body fat Mass (Kg) / Body weight (Kg)] × 100

Body fat includes essential body fat and storage body fat. Essential body fat is necessary to maintain life and reproductive functions. The percentage of essential body fat for women is greater than that for men, due to the demands of childbearing and other hormonal functions. The percentage of essential fat is 3–5% in men, and 10-16% in women. Storage body fat consists of fat accumulation in adipose tissue, part of which protects internal organs in the chest and abdomen.

Visceral Fat:

In humans, adipose tissue is located beneath the skin (subcutaneous fat), around internal organs (visceral fat), in bone marrow (yellow bone marrow) and in breast tissue.

BMR (RMR): Basal metabolic rate (BMR), and the closely related resting metabolic rate (RMR), is the amount of energy expended daily by humans and other animals at rest. Rest is defined as existing in a neutrally temperate environment while in the post-absorptive state. In plants, different considerations apply.

The release, and using, of energy in this state is sufficient only for the functioning of the vital organs, the heart, lungs, nervous system, kidneys, liver, intestine, sex organs, muscles, and skin.

BMR generally decreases with age and with the decrease in lean body mass (as may happen with aging). Increasing muscle mass increases BMR. Aerobic fitness level, a product of cardiovascular exercise, while previously thought to have effect on BMR, has been shown in the 1990s not to correlate with BMR, when fat-free body mass was adjusted for New research has, however, come to light that suggests anaerobic exercise does increase resting energy consumption. Illness, previously consumed food and beverages, environmental temperature, and stress levels can affect one's overall energy expenditure as well as one's BMR.

Skeletal muscle:

Skeletal muscle is a form of striated muscle tissue existing throughout the human body, and which is under control of the somatic nervous system; that is to say, it is voluntarily controlled. It is one of three major muscle types, the others being cardiac and smooth muscle. As their name suggests, most skeletal muscles are attached to bones by bundles of collagen fibers known as tendons.

Biological (Real) Age:

Biological age is how time and lifestyle have affected organs and cells compared to other people of chronological age. Factors of biological aging include changes in the physical structure of the body as well as changes in the performance of motor skills and sensory awareness. Chronological age is current age in years, calculated from birth date.

RESULTS AND DISCUSSION

Table 1: Interpretation of Body Composition Report

Body Fat %	**Gender**		**Low**	**Normal**	**High**	**Very High**
	Female		Up to 19.9	20-29.9	30-34.9	35 & more
	Male		Up to 9.9	10-19.9	20-24.9	25 & more
Trunk Fat <15 Normal, 16-18 High, 18+ Very high						
Visceral Fat			**%**	**0(Normal)**	**+(High)**	**++(Very High)**
				0.5-9.5	10.0-14.5	15.0-30.0
Skeletal Muscle %	**Gender**	**Age**	**–(Low)**	**0(Normal)**	**+(High)**	**++(Very High)**
	Female	18-39	< 24.3 %	24.3-30.3 %	30.4-35.3 %	≥ 35.4 %
		40-59	< 24.1 %	24.1-30.1 %	30.2-35.1 %	≥ 35.2 %
		60-80	< 23.9 %	23.9-29.9 %	30.0-34.9 %	≥ 35.0 %
	Male	18-39	< 33.3 %	33.3-39.3 %	39.4-44.0 %	≥ 44.1 %
		40-59	< 33.1 %	33.1-39.1 %	39.2-43.8 %	≥ 43.9 %
		60-80	< 32.9 %	32.9-38.9 %	39.0-43.6 %	≥ 43.7 %
BMI			**Underweight**	**Normal**	**Over weight**	**Obese**
			Up to 18.4	18.5-24.9	25-29.9	30 & more

Table2: Different Body Composition Readings are as follows.

Case No. Male / Female	Date	Age	Ht	Wt Kg	Fat %	Subcutaneous Fat %				Visceral Fat %	Skeletal Muscle %				RM Kcal	BMI	Body Age
						Whole Body	Trunk	Arms	Legs		Whole Body	Trunk	Arms	Legs			
1 M	28.11.12	90	149	48.5	37.8		24.8			10	20.3				1175	21.8	66
2 F	14.11.12	76	149	63.2	45.5		37.6			15	17.9				1240	28.3	80
	29.11.12	76	149	63	46.5		38.2			14	17.5				1233	28.4	80
	09.12.12	76	149	62.9	44.1	36.9	34.3	57.3	50	14	18.5	12.5	18.3	31.4	1242	28.3	80
	17.01.13	76	149	63.1	48.9	39.4	37.6	-	56.2	15	16.6	11	16.1	28.4	1223	28.4	80
3 M	26.11.12	62	170	78.9	32.2		22.2			16	26.8				1683	27.3	65
4 M	26.11.12	59	177	61.6	30.5		19.9			5	28.9				1431	19.7	46
5 F	26.11.12	53	145	89.3	47.8		46.8			30	17.6				1599	42.5	80
6 M	27.11.12	57	167	66	30.8		20.8			11	27.4				1491	23.7	55
7 M	30.11.12	53	172	53.8	23.4		15.3			3	31.1				1334	18.2	34
	09.12.12	53	172	54.9	22.2	14.6	12.4	20.3	20.2	3.5	31.3	24.9	37.7	48.7	1355	18.6	35
	16.01.13	53	172	55.3	22.6	14.8	12.6	20.6	20.5	3.5	31.2	24.8	37.9	48.6	1361	18.7	36
8 F	27.11.12	50	151	46.4	35.5		26.8			4	22.1				1037	20.3	47
9 F	12.11.12	47	148	37.6	24.7		24			2	22.3				908	17	34
	19.11.12	47	148	38	37.8		25.8			2	21.3				906	17.3	37
	28.11.12	47	148	38.9	29.6		22			2	23.4				939	17.8	36
	09.12.12	47	148	38.3	33.7	23.8	22	44.5	33.6	2	22.3	18	28.1	31	920	17.5	36
	13.01.13	47	148	37.7	32.2	22.9	20.8	42.8	32.3	2	22.6	18.3	28.6	31.7	914	17.2	35
10 M	28.11.12	46	172	78.9	30.9		21.3			13	28.5				1699	26.7	55
11 F	12.11.12	45	159	63.1	43.2		36.8			12	19.5				1254	28.8	60
	28.11.12	45	159	62.2	38.9		31.6			7	21.8				1263	24.6	55
	09.12.12	45	159	62.2	38	31.2	28.3	51.5	45.2	7	22.2	16.8	22.8	34.1	1269	24.6	55
	16.01.13	45	159	62.4	37.8	31.1	28.2	51.1	44.9	7	22.3	16.9	22.9	34.7	1272	24.7	55
12 F	25.11.12	45	156	62.4	39.5		32.7			8	21.4				1263	25.6	57
	17.01.13	45	156	63.2	40.1	33.2	30.4	54.3	48.4	8.5	21.2	15.8	21.5	33.6	1272	26	58
13 M	17.01.13	42	173	88.9	29.5	20.9	19.3	27.5	27.9	16.5	29.5	21.5	34.5	46.9	1868	29.7	57
14 F	28.11.12	34	163	57.6	31.4		25.7			4	25.3				1230	21.7	38
	17.01.13	34	163	57.9	30.7	25.5	22	42.9	37.4	3.5	25.6	20.3	27.7	37.6	1237	21.8	38
15 F	30.11.12	24	156	64.9	38.2		32.8			7	22.5				1309	26.7	43
16 F	27.11.12	23	162	43.2	20.8		16.7			1	29.2				1041	16.5	18
	09.12.12	23	162	44.1	21.3	17.2	13.2	32.8	28.4	0.5	29	24.9	34.8	39.2	1054	16.8	18
	17.01.13	23	162	44.6	21.3	17.3	13.2	32.7	28.4	0.5	29.1	24.9	34.7	39.5	1063	17	18
17 F	16.11.12	22	161	52.6	31.2		24.7			3	25.6				1155	20.4	26
	25.11.12	22	161	52.2	32.4		25.1			2	25.3				1145	20.1	26
	29.11.12	22	161	52.2	31.8		24.8			2	25.5				1147	20.1	26
	09.12.12	22	161	52	31.6	24.7	21.8	45	38.9	2.5	25.6	21.2	29	35.8	1145	20.1	25
	17.01.13	22	161	51.8	32.3	25	22.2	45.8	39.3	2.5	25.3	21	28.7	35.3	1139	20	26
18 M	28.11.12	16	176	50.2	10.9		7.2			-	38.9				1334	16.2	-
19 F	28.11.12	14	160	41	17.8		14.9			-	30.9				1017	16	-
	16.01.13	14	160	41.7	18.5	15.4	11	30.1	26.9	-	30.4	26.6	36.8	40.2	1025	16.3	-

Case No.1 Male Ideal weight can be calculated as 48.8 Kg and actual weight is 48.5 i.e. Normal. Fat 37.8 % very high. Trunk fat 24.8 very high. Visceral fat 10 % High. Skeletal muscle 20.3 % Low. RM 1175 Kcal, BMI 21.8 Normal. Body age 66.

Case No.2 Female Ideal weight can be calculated as 48.8 and actual weight is 63.2 Kg i.e. 14.4 Kg over weight. Fat % is 45.5 very high. Trunk fat is 37.6 very high, Visceral fat 15 % very high. Skeletal muscle 17.9 % Low. RM 1240 Kcal, BMI 28.3 Overweight. Body age 80 high.

Case No.3 Male Ideal weight can be calculated as 63.6 Kg and actual weight is 78.9 Kg i.e. 15.3 Kg over weight. Fat % is 32.2 very high. Trunk fat is 22.2 very high, Visceral fat 16 % very high. Skeletal muscle 26.8 % Low. RM 1683 Kcal, BMI 27.3 Overweight. Body age 65 high.

Case No.4 Male Ideal weight can be calculated as 68.9 Kg and actual weight is 61.6 Kg i.e. 7.3 Kg under weight. Fat % is 30.5 very high. Trunk fat is 19.9 very high, Visceral fat 5 % normal. Skeletal muscle 28.9 % Low. RM 1431 Kcal, BMI 19.7 normal. Body age 46 low.

Case No.5 Female Ideal weight can be calculated as 46.3 and actual weight is 89.3 Kg i.e. 43 Kg over weight. Fat % is 47.8 very high. Trunk fat is 46.8 very high, Visceral fat 30 % very high. Skeletal muscle 17.6 % Low. RM 1599 Kcal, BMI 42.5 very severely obese. Body age 80 high.

Case No.6 Male Ideal weight can be calculated as 61.4 Kg and actual weight is 66 Kg i.e.4.6 Kg overweight. Fat 30.8 % very high. Trunk fat 20.8 very high. Visceral fat 11 % High. Skeletal muscle 27.4 % Low. RM 1491 Kcal, BMI 23.7 Normal. Body age 55 low.

Likewise other cases can be interpreted.

CONCLUSION

Case No.1 Male In this case skeletal muscle % and RM has to be increased so that body fat % can be decreased.

Case No.2 Female In this case skeletal muscle % and RM has to be increased so that weight, body fat % , trunk fat , visceral fat, BMI and body age can be decreased. And has to undergo 10 month weight loss programme to lose 14.4 kg weight.

Case No.3 Male In this case skeletal muscle % and RM has to be increased so that weight, body fat % , trunk fat , visceral fat, BMI and body age can be decreased. And has to undergo 11 month weight loss programme to lose 15.3 kg weight.

Case No.4 Male In this case skeletal muscle % and RM has to be increased so that body fat % , trunk fat can be decreased and has to undergo 5 month weight gain programme to increase 7.3 kg weight.

Case No.5 Female In this case skeletal muscle % and RM has to be increased so that weight, body fat % , trunk fat , visceral fat, BMI and body age can be decreased. And has to undergo 29 month weight loss programme to lose 43 kg weight.

Case No.6 Male In this case skeletal muscle % and RM has to be increased so that weight, body fat % , trunk fat and visceral fat can be decreased. And has to undergo 3 month weight loss programme to lose 4.6 kg weight.

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