BIOELECTRICAL IMPENDANCE ANALYSIS OF BODY COMPOSITION IN PATIENTS WITH CHRONIC HEART FAILURE

Gulatava N., Tabagari N., Tabagari S.

David Tvildiani Medical University, Tbilisi, Georgia

As it is well-known, bodyweight and body mass index (BMI) are inadequate markers in elderly population and patients with diseases due to changes in body composition [1-5]. In fact, the body composition is the determinant of health and also of a prognosis [1]. Therefore, assessment of Fat Free Mass (FFM) is an object of interest for evaluation of nutritional status in scopes of epidemiological, clinical and scientific researches. Low FFM is often present in elderly patients with chronic conditions, such as COPD [3], chronic heart diseases [4] and cancer [5]. Diagnosis of Cachexia is also validly associated with morbidity and mortality. It is also important that low FFM is often present in normal and overweight populations ("Sarcopenia") and is associated with poor outcomes [2,5]. Therefore, evaluation of body composition is significant in different population and morbidity groups; Nevertheless, the equipment, necessary for recommended methods (skin-fold anthropometry, dual-energey X-ray absorptiometry etc.) is expensive, requires competent staff, a good deal of time and therefore, their use in clinical settings is limited. Bioelectrical impedance method (BIA) is the good alternative owing to high validity, non-invasiveness, simplicity and safety [6-10].

BIA is based on conductivity of electrical current via bodily fluids [7]. It is tested on various populations and reference values of measurements for different age groups are already accepted. Often, they are corrected by height and calculated by FMM index (FFMI; FFM/height^2); However, there are no sufficient data for patients with different diseases; Reference values are not compatible with overweight and obese individuals; However, according to WHO data, this problem becomes more significant: 35% of general population is overweight and 11% - obese. This is also important from the viewpoint of "sarcopenic obesity" [11] proportionally connected with FFMI [12]. In the aspect of body composition, in order to devise clinical recommendations, one of the focus groups of morbidity includes patients with chronic heart failure, where excess as well as deficiency of fat mass should have an effect on the patients outcome and quality of life. The goal of our study was to analyze the characteristics of body composition in patients with different severities of chronic heart failure.

Material and methods. Conducted research was prospective and observational; 86 patients - consistent with study purposes and 30 practically healthy individuals were enrolled. Inclusion criteria were presence of the chronic heart failure, desire to participate in the study. Every patient was selected from the outpatient department of "New Hospitals" (Tbilisi, Georgia). Verification of diagnosis was made based on cardiovascular anamnesis, clinical laboratory test data and conclusion of echocardiography using standard techniques and an experienced cardiologist evaluated the class of HF (according to NYHA). Patients with different functional classes of chronic heart failure (NYHAII/III/IV) were receiving standard treatment.

For several years prior to inclusion, patients had been treated as mentioned above. Since BIA is not sufficiently validated for patients with BMI less than 14kg/m^2 and more than 36kg/m^2 were not considered for inclusion [2,13]. Another exclusion criterion was MI within the past three months, signs of acute infectious diseases, autoimmune diseases, renal failure (serum creatinine >200 mg/%) and severe hepatic diseases; Patient with suspected malignization were not included in the study, either. Study protocol was defined in accordance with guidelines of ethics committees. Every individual included in the study signed the informed consent forms.

Body weight was measured with 0.1kg accuracy by means of balance weight machine. Height of erect body and waist circumferrence measurements were taken in the morning, with accuracy of 0.5cm with light clothing. Hip circumferrence was measured at the point of the widest circle. Ration of the waist to the hip circumferrence was calculated as follows: Waist circumferrence(cm)/ Hip circumferrence (cm). BMI was calculated as ratio of the body weight to the square of the height. BMI categorization: underweight (<18.50 kg/m^2), normal weight (<18.50 -24.99 kg/m^2), overweight (25.00 – 29.99 kg/m^2) and obese (>30.00 kg/m^2) [2,14].

Measurement Of Body Composition with BIA Method. Bioelectrical impedance was measured by means of BIA 450, BIODYNAMICS (USA) in accordance with standard procedures widely accepted in clinical practice: Patient was laid on the back, two pairs of sensor pads were placed on patients - One pair on right waist and hand another pair on the right leg and foot. Generator of the analyzator produced 50kHZ and 800μA electrical currency that is transmitted to the skin via adhesive electrodes. Prior to the procedure the 70% ethylene solution was applied to the skin. Patients followed the instructions in advance – not to perform physical excercise, not to consume coffeine and not to eat 4 hours prior to procedure; they were allowed to drink 2-4 cups of water no less than 2 hours prior to the procedure.

Fat Free Mas was determined by BIA Method. This parameter was also calculated using prediction equation based on BIA and anthropometric parameters: FFM (kg) = 11.78 + (0.499 x H^2/R) + (0.134 x Weight) + (3.449 x gender), where H stands for height in cm, R represents resistance in Ω, Weight is measured in kg and "gender" equals to 0 for females and 1 - for males (3). FFMI equals to the ratio of FFM (kg) to the square of the height; Ratio of FMI – FM (kg) to the square of the height.

Echocardiography. Echocardiography was performed by experienced echocardiographers using the standard techniques. The echocardiographic parameters included: left ventricular ejection fraction (LVEF); Left ventricular Diastolic Diameter (LVDD), Interventricular septum (IVS), Left ventricular posterior wall (LVPW), right ventricular (RV), pulmonary pressure (PASP max). All measurements were performed using ultrasound systems AplioXG (Toshiba, Japan).

Descriptive statistics of normal distribution is represented by means±SD and their dispersion analysis, ANOVA and student *t*-test. For categorical data, and the data that were categorized, univariate frequency analysis, as well as bivariate data comparative analysis using Pearson'sχ^2, were performed.

Spearman's correlation analysis was also performed. For all comparisons P<0.05 was considered statistically significant. Statistics were processed using software program (SPSS V.24.0 IBM).

Results and discussion. 116 individuals, 48 men and 38 women, were enrolled into the study. They were divided into two groups – 86 patients with chronic heart failure and control group of 30 practically healthy individuals. Patients with heart failure were divided into subgroups of 26/54/6 according to the severity of the chronic heart failure (NYHA II/III/IV). General characteristics of the study subjects is given in the Table 1.

Table 1. Anthropometric and bioelectrical impedance data of study subjects

Parameters	Patient	Control Group
Number (female/male)	86 (38/48)	30 (17/13)
Age	69,85 ±12.4	58.74 ±9.4
Weight, kg	79.99±15.6	80.51±15.2
Body Mass Index (BMI)	28.05±4.3	27.6± 4.3
Underweight, n (%)	2 (1.5%)	1 (1%)
Normal weight, n (%)	27 (20.8%)	6 (17.6%)
Overweight, n (%)	36 (27,7%)	9 (26,5%)
Obesity, n (%)	52 (47.9%)	14 (41.2%)
Fat free mass (FFM) (Lean body mass), kg (BIA method)	52,1±15,4	52,9±13.3
Fat free mass (FFM), kg (prediction equation)	28.55 ±5.1	24.74 ±9.64
Fat free mass index (FFMI), kg/m^2	11.9±10.5	8.6±3.3
Fat mass (FM), kg	35,4±18,5	33,2±15.5
Fat mass index (FMI), kg/m^2	17.1±29.4	10.1±6.3
Fat mass, %	39.7±13.1	37.8±11.3
Functional class of heart failure (II/III/IV)	26/54/6	0
Arterial hypertension, (%)	84.4%	44.11%
Diabetes Mellitus Type II (%)	23.1%	1 %

Table 2. Body composition data in males and females of control group and patients with chronic heart failure

Parameters	Group			Patient			Control Group		
	Patient	Control group	*p1*	Female	Male	*p2*	Female	Male	*p3*
Resistance	588.43 ±148.3	590.01 ±137.79	0.959	637.16 ±160.57	549.82±126.47	0.005**	612.15±97.58	561.05±177.72	0.323
Reactance	66.53 ±35.85	90.51±43.62	0.009**	62.95±34.83	69.37±36.71	0.389	88.74±34.79	92.82±54.54	0.805
Lean body mass, kg	52.15 ±15.45	52.94±13.35	0.801	45.18±13.68	57.68±14.62	0.000	49.1±11.04	57.97±14.83	0.131
Lean body mass, %	60.34 ±13.1	62.2±11.34	0.485	57.79±14.17	62.35±11.94	0.092	59.45±9.96	65.8±12.41	0.071
Fat Free Mass, kg	28.55 ±5.1	24.74±9.64	0.034*	24.98±4.52	31.44±3.47	0.000**	22.16±9.69	28.43±8.58	0.060
Fat Free Mass Index, kg/m^2	11.94 ±10.50	8.57±3.29	0.069	10.28±6.48	13.28±12.78	0.165	7.98±3.51	9.41±2.87	0.220
Fat mass,kg	35.36 ±18.52	33.19±15.52	0.562	34.13±18.18	36.34±18.91	0.567	35.49±18.39	30.18±10.67	0.363
Fat Mass Index, kg/m^2	17.09 ±29.43	10.12±6,26	0.174	14.63±18.17	19.09±36.15	0.463	10.75±7.36	9.22±4.33	0.492
Body mass index (BMI)	30.1 ±8.93	28.7±5.13	0.432	28.37±5,47	28.49±4.58	0.101	31,48±10.8	28.95±5.89	0.818
Fat Mass, %	39.66 ±13.10	37.80±11.34	0.485	42.21±14.17	37.65±11.94	0.663	40,55±9.96	34.20±12.41	0.358
Waist circumference, cm	116.53 ±5.68	95.38±24.56	0.001**	115.12±4.23	89.18±26.01	0.021*	117.68±6.44	102.2±22.14	0.234
Waist circumferrence / Hip circumferrence	1.02 ±0.04	1.81±0.44	0.000**	1.03±0.05	1.02±0.03	0.085	1.56±0.47	2.01±0.31	0.056

*** - correlation is significant at the 0.01 level (2-tailed); * - Correlation is significant at the 0.05 level (2-tailed).*
P1-Patient/Control group; P2- Male/Female; P3- Male/Female Control Group

Table 3. Measurements of body composition in patients with different functional classes of chronic heart failure

Parameters	II f.c.	III f.c.	IV f.c	*p1*	*p2*	*p3*
Number of patients	26	54	6			
Phase_angle	6,762	6,502	4,350	,723	,046	,112
Body capacitance pF	631,615	653,704	530,167	,790	,503	,411
Resistance	630,169	574,696	512,083	,111	,088	,349
Reactance	73,681	66,515	39,783	,423	,020	,111
Body cell mass,kg	22,262	24,046	24,117	,460	,699	,984
Body cell mass,%	25,515	27,865	27,167	,243	,668	,837
Extracellular mass,kg	26,750	29,157	35,217	,238	,049	,096
Extracellular mass,%	30,104	33,963	41,000	,044	,002	,066
Lean body mass, kg	48,915	53,204	59,333	,289	,209	,315
Lean body mass, %	55,692	61,828	68,167	,051	,032	,271
Fat_masskg	38,854	34,852	28,000	,395	,178	,419
Fat_mass%	44,308	38,172	31,833	,051	,032	,271
ECM/BCM	1,255	1,280	1,522	,730	,065	,078
Body mass index (BMI)	47,842	42,648	29,633	,708	,455	,586
Basal metabolic rate ,cals	1526,231	1645,204	1851,167	,347	,210	,285
Intracellular water,L	19,973	21,026	21,467	,535	,691	,877
Intracellular water,%	55,608	54,202	47,800	,497	,026	,098
Extracellular water, L	15,765	17,711	23,317	,177	,019	,034
Extracellular water,%	44,392	45,783	52,200	,502	,026	,097
Total body water	35,738	38,737	44,783	,245	,151	,168
Lean Body Mass	73,492	73,548	74,967	,971	,675	,534
Waist circumference, cm	116,577	116,722	118,500	,919	,477	,480
Hip circumference, cm	114,154	114,500	117,667	,827	,258	,241
Waist circumferrence / Hip circumferrence	1,022	1,021	1,008	,872	,352	,518

p_1 - IIf.c /IIIf.c; p_2 - IIf.c/ IVf.c; p_3- IVf.c/IIIf.c

Study showed that in both patients' and control groups, underweight, as well as overweight individuals are present. also, in both groups, obesity, as determined by BMI, is most common. Due to differences between male and female body composition norms, average group data of the patients' and control groups were studied in subgroups split by gender (Table 2). Table shows that groups are not different in BMI, while abdominal obesity parameters (waist circumference, Waist/Hip ratio) differ in patients' group and this difference is statistically valid. These groups also differ in reactance and FFM. There was no statistically significant difference between male subgroups of patient and control groups; Valid differences in resistance, lean body mass and fat free mass (kg) were observed between female subgroups. Analysis of body composition characteristics within subgroups of different severity of disease (Table 3) revealed that functional classes differ by BIA data, including phase angle, reactance, extracellular mass (kg), extracellular mass (%), lean body mass (%), fat mass (%), intracellular water (L), extracellular water (%) and extracellular water (L).

At first sight, results might seem paradoxical; namely, FFM data is higher in patients group compared to control; Also, non-uniform data of lean body mass (BIA) and FFMI in comparison (Patient's and control group as well as gender groups) groups (Table 2) shows, that lean and fat composition of the body is affected by age , weight (many studies of reference values are based on such approaches) [15,16].

BIA has been shown to be more accurate for determining leanness or fatness in human [7,17]. BIA provides a more reliable measurement of body composition with respect to FFM and FM than does BMI, this is also confirmed by our data and is consistent with studies conducted in other population groups [3-5], including healthy [18] and including the elderly population [17].

According to the results of our study, reduction of the fat mass (%) and increase in lean mass (%) in overweight and obese (I degree) populations does not reflect (according to our data) better clinical condition and/or prognosis and should be dependent on abnormal hydration in patients with chronic heart failure: Disorders of balance of extracellular/intracellular water during weight gain (Table 3).

The same table reveals that during chronic heart failure, regardless of the hydration status, Reactance (statistically valid), resistance and phase angle, believed not to be dependent hydration status, decrease. The value of the phase angle is reduced when compared to the data of the II and IV functional classes ($P<0.046$). Although the biological significance of this value is not fully understood, it is known by now that it reflects the mass

of body cells and is used as an indicator of nutritional status in children and adults. Reduction of this value together with worsening of chronic heart failure, without significant changes in cellular mass, suggests nutritional (presumably cellular nutrition) problems. It is also important that this parameter (Phase angle) is considered as the best value for assessment of functional status of cellular membrane and its low value is associated with a high risk of disease. In this case it's reduction (from second to fourth functional classes) represents severity of the disease.

Finally, analysis of body composition in patients with CHF shows that groups of patients with CHF (classified according to the severity of the disease) differ in a number of BIA parameters that may reflect nutritional status problems (especially at the cellular level), including cell membrane function. Phase angle decreases shown a high risk of disease exacerbation / severity of disease.

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SUMMARY

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Gulatava N., Tabagari N., Tabagari S.

David Tvildiani Medical University, Tbilisi, Georgia

Evaluation of body composition is important in countries of different populations and morbidities. One of the groups of morbidity consists of patients with chronic heart failure, where the body fat mass as well as fat-free mass and several other parameters are likely to have an impact on severity and/or outcome of the disease and patient's quality of life.

The purpose of the study was to analyze the parameters of body composition in patients with chronic heart failure.

Study included 86 patients, fit for the purpose of the study, and 30 practically healthy individuals.

Body mass and other measurement data (height, waist circumference, hip circumference and waist-to-hip ratio, anthropometric measurements) were evaluated.

Bioelectrical impedance (BIA) was analyzed by BIA 450, BIODYNAMICS (USA) in accordance with standard procedures that are widely accepted. Fat free mass (FFM) was determined by the BIA method. This index was also calculated by prediction equation based on BIA and anthropometric parameters: FFM (kg) = 11.78 + (0.499 x H^2/R) + (0.134 x Weight) + (3.449 x gender), where H stands for height in cm, R represents resistance in Ω, Weight is measured in kg and "gender" equals to 0 for females and 1 - for males (3). FFMI equals to the ratio of FFM (kg) to the square of the height; Ratio of FMI – FM (kg) to the square of the height.

Study showed that in both patients' and control groups, underweight, as well as overweight individuals are present; also, in both groups, obesity, as BMI category, is most common.

Groups (patients vs control) differed in Reactance and FFM (kg) ($P<0.009$). There was no statistically significant difference between male subgroups of patient and control groups; Valid

differences in resistance, lean body mass and fat free mass (kg) were observed between female subgroups.

Analysis of body composition characteristics in patients with chronic heart failure revealed that functional classes of heart failure differ in several BIA data, including resistance, Lean body mass (kg) and Fat Free Mass (%).

Keywords: Body compositions, Fat Free Mass, Fat mass, Fat Free Mas Index, Fat Mass Index, Bioelectrical impedance method, Resistance, Reactance, phase angle, CHF, Wrist-Hip Ratio.

РЕЗЮМЕ

ОЦЕНКА ПОКАЗАТЕЛЕЙ КОМПОЗИЦИИ ТЕЛА МЕТОДОМ БИОЭЛЕКТРИЧЕСКОГО ИМПЕДАНСА У ПАЦИЕНТОВ С ХРОНИЧЕСКОЙ СЕРДЕЧНОЙ НЕДОСТАТОЧНОСТЬЮ

Гулатава Н.А.,Табагари С.И., Табагари Н.С.

Медицинский университет им. Давида Твилдиани, Тбилиси, Грузия

Оценка состава/композиции тела имеет большое значение в разных популяционных средах и при разных заболеваниях. Одно из таких заболеваний - это хроническая сердечная недостаточность, при которой как жировая масса тела, так и свободная от жира, влияют на тяжесть заболевания, качество жизни и исход заболевания.

Цель исследования оценка состава/композиции тела у пациентов при различной тяжести сердечной недостаточности.

В исследовании участвовали 96 пациентов и 30 практически здоровых лиц.

Масса тела, рост, окружность талии, окружность бедра, их соотношение измеряли стандартными методами.

Биоэлектрическое сопротивление рассчитано с использованием аппарата BIA 450, BIODYNAMICS (USA) соответственно стандартным процедурам. Fat Free Mass определили BIA методом, рассчитано прогностическое уравнение с использованием BIA показателей и антропометрических данных:

FFM (кг) =11.78+(0.499 X H^2/R) + (0.134 X масса тела) + (3.449 X пол),

где H - рост в см, R – резистентность в **Ω**, масса – в кг и пол = 0 женский и 1 – мужской. FFMI – рассчитывается как соотношение FFM (кг) к росту^2; FMI – рассчитывается как соотношение FM (кг) к росту^2.

Исследование показало, что среди больных хронической сердечной недостаточностью и практически здоровых встречаются лица как с излишним весом, так и дефицитом массы тела. В процентном соотношении в обеих группах чаще отмечался избыток массы тела.

Группы (пациенты vs контрольная группа) достоверно ($p<0.009$) отличаются по показателям Reactance и FFM (кг). Достоверные различия между женским и мужским полом у не обнаружены; среди представителей женского пола выявлены достоверные отличия по показателям Resistance, Lean body mass (кг) и Fast Free Mass (кг).

Среди пациентов с хронической сердечной недостаточностью анализ состава/композиции тела в зависимости от тяжести заболевия и функционального класса показал различия между функциональными классами по показателям Resistance, Lean body mass (кг) и Fat Free Mass (%).

რეზიუმე

ბიოელექტრული იმპედანსის მეთოდით განსაზღვრული სხეულის კომპოზიციის მაჩვენებლები გულის ქრონიკული უკმარისობით პაციენტებში

ნ.ღულათავა, ს.თაბაგარი, ნ.თაბაგარი

დავით ტვილდიანის სამედიცინო უნივერსიტეტი, თბილისი, საქართველო

სხეულის კომპოზიციის შეფასებას დიდი მნიშვნელობა ენიჭება სხვადასხვა პოპულაციურ წრეებისა და დაავადებების მიმდინარეობის, მკურნალობის და გამოსავალისათვის. ავადმყოფების ერთ-ერთ ასეთ ჯგუფს წარმოადგენს გულის ქრონიკული უკმარისობით პაციენტები, რომლებსაც როგორც სხეულის ცხიმოვანი მასას,ასევე ცხიმისგან თავისუფალი მასას მნიშვნელოვანი გავლენა აქვს დაავადების სიმძიმეზე, ცხოვრების ხარისხზე და გამოსავალზე.

კვლევის მიზანს წარმოადგენდა ორგანიზმის კომპოზიციური მახასიათებლების ანალიზი პაციენტებში გულის ქრონიკული უკმარისობის სხვადასხვა სიმძიმით.

კვლევაში ჩართული იყო 96 პაციენტი და 30 პრაქტიკულად ჯანმრთელი პირი.

სხეულის წონის, სიმაღლის, წელისა და თეძოს გარშემოწერილობის,მათი ფარდობის გამოთვლა ხდებოდა სტანდარტული მეთოდების გამოყენებით.

ბიოელექტრული იმპედანსის გაზომვა განხორციელდა BIA 450, BIODYNAMICS (USA) გამოყენებით, სტანდარტული პროცედურების შესაბამისად. ცხიმისგან თავისუფალი მასა განსაზღვრული იყო BIA მეთოდით, ასევე პროგნოსტული განტოლებით BIA-სა და ანტროპომეტრიული პარამეტრებზე დაფუძნებით:

ცხიმისგან თავისუფალი მასა (კგ) = 11.78 + (0.499 X H^2/R) + (0.134 X წონა) + (3.449 X სქესზე),

სადაც H - სიმაღლე სმ-ში,R - რეზისტენტობა **Ω** - ში, წონა – კგ-ებში, სქესი = 0 ქალებისთვის და 1 – მამაკაცებისთვის. ცხიმისგან თავისუფალი მასის ინდექსი (FFMI) გამოთვლა განხორციელდა ცხიმისგან თავისუფალი მასის (კგ) ფარდობით სიმაღლის კვადრატზე; ცხიმოვანი მასის ინდექსი (FMI) – ცხიმოვანი მასის (FM) (კგ) ფარდობით სიმაღლის კვადრატზე.

კვლევამ აჩვენა, რომ როგორც პაციენტთა, ასე საკონტროლო ჯგუფში გვხვდება როგორც წონის ნაკლებობით, ასე სიჭარბით პირები; ორივე ჯგუფში სიმსუქნე, როგორც სმი-ის კატეგორია პროცენტულად ქვეყანაზე ხშირია.

ჯგუფები (პაციენტთა vs საკონტროლო) სარწმუნოდ ($p<0.009$) განსხვავდება Reactance და FFM (კგ) – მაჩვენებლით. პაციენტთა და საკონტროლო ჯგუფის მამაკაცის ქვეჯგუფებს შორის სტატისტიკურად სარწმუნო განსხვავება არ გამოვლინდა; ქალები – სარწმუნოდ განსხვავდებიან რეზისტანსის, Lean body mass (კგ) და Fast Free Mass (კგ) მიხედვით.

გქუ-ით პაციენტებში სხეულის კომპოზიციური მახასიათებლების ანალიზმა დაავადების სიმძიმის მიხედვით განაწილებულ ჯგუფებში აჩვენა ფუნქციური კლასების განსხვავება BIA-ს ისეთი მონაცემებით, როგორიცაა Resistance, Lean body mass(kg) და Fat Free Mass (%).