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BIA Resistance and Reactance: Correlation with Somatic Features and Peritoneal Dialysis Treatment in 17 Males and 32 Females

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***Abstract*— The comparison of basal data of males versus females showed no differences in the following parameters: age, body structure (BMI), glucose concentrations in dialysis solutions, and fat mass in kg; even fat mass calculated as percentage of weight was significantly higher in females. The same equality resulted for metabolic and nutritional variables, namely, measurements of BUN, albuminemia, triglycerides, hemoglobinemia, hematocrit, lymphocytes, C3, IgG, and for all data concerning dialysis. Females presented with higher levels of cholesterolemia and higher body water composition, particularly extracellular water with respect to the lean mass, as shown by the ratio of extracellular water (in kg) per cellular mass (in kg). An adequate prediction by the resistance and reactance of the variables previously reported resulted in significant correlations and was stated by egressions. The result was assumed to be positive when the differences between the actual and predicted variables were between the mean+2SD and the mean-2SD, and inside ± 10%; this corresponded to a range that included by default 98% of the values of an item's distribution. In males, resistance correctly predicted reactance, BMI, the liters of dialysis solutions with 1.36% of glucose, and cellular mass (kg). In females, resistance correctly predicted the liters of dialysis solutions with 1,36% of glucose. The efficacy of the regressions greatly differed between males and females, because males attained the target only for 40% of the considered variables, while the female regressions attained the target for all the considered variables (100%). This resulted in divergence in the power of prediction of resistance and reactance between males and females, and variables of different matters resulted in significant correlations with resistance and reactance in males versus females.**

***Index Terms*— resistance, reactance, body components, correlations.**

I. INTRODUCTION

Highlight Premise - The tools to be considered as the golden standard to evaluate the non-directly measurable body parameters are represented by: 1) deuterium or tritium dilution; 2) bromine space - 3) water or air plethismography; 4) total body potassium (TBK) levels; 5) magnetic resonance imaging (MRI); 6) computerized tomography (CT) scans; and 7) Dual Energy X-ray Absorptiometry (DEXA) used to measure the calcium concentration in the bones. Methods 1, 2, and 3 are used to evaluate body water content, while method 4 measures cellular mass, because the greatest proportion of body potassium is inside the cells and not in body fat, as shown by Forbes GB et al. [1], who indirectly calculated the fat body content by defining the lean body mass using potassium^{40}, and from this an estimate of muscle mass. This last measurement may also be evaluated using methods 5 and 6, which are more usually used to diagnose diseases by the induced morphologic deviations. Starting in the 1960s, a new method was developed to study body composition. It was based on the measurement of the body's resistance and reactance (impedance) during the passage of an electric current. This was formulated according to two different aspects of the opposition of the human body to the passage of an electrical current: the resistance, which is the opposition to the passage of electric current through the body, due to the cells and to the body's water, and the reactance, which is the opposition due to the phenomena of energy stores in cells. The method was given the acronym BIA, or Bio Impedance Analysis. This method was progressively studied and developed during the following years, first by Thomasset in 1963 [2] and Hoffer in 1969 [3]. Hoffer improved the first results, using a currency set at 100 kHz of frequency. Lukasky [4] confirmed the existing high correlation between resistance and TBK (total body potassium^{40}), free fat mass (FFM), and total body water (TBW), (r = 0.96, 0.98, and 0.95 respectively; p = 0.0001), and proceeded to estimate TBW by impedance using two frequencies. The method underwent many modifications in the following years by Lukasky in 1985 [4], Janssen in 2000 [5], Corcoran [6] in 2000, Piccoli in 2005 [7], Donadio in 2007 [8], and Earthman in 2007 [9]. These last authors, particularly Earthman, introduced a new system based on the use of electric currency at increasing frequencies, named the bioimpedance spectroscopy (BIS), with frequencies ranging from 5 to 1000 kHz, which pointed out a particular frequency , which allowed the identification of the so-called frequency f_c, or characteristic frequency, the frequency by which "the effects of cellular capacitance are the highest ones", practically speaking, "the frequency generating the best definition of intracellular water" [10], based on the cellular capacitance, that is the capability of a cell to act as an accumulator. The present paper aims to study the correlations existing between the resistance and the reactance and the data concerning the body composition and the dialytic treatment of a population of 17 males and 32 females undergoing chronic peritoneal dialysis.

Results

Tables I and II show the 36 available data concerning the studied population, and their comparison between males and

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females. Nonstatistically significant comparisons are emphasized in bold.

Table I - Comparison of available data in males versus females

Variables		Male data	Female data	Statistics	
n.		Mean±SD	Mean±SD	T value	P value
1	Resistance	488.2±89.7	562.7±85.9	-3.6	0.001
2	Reactance	47.76±9.24	53.2±11,..16	-2.32	0.023
3	Age	58.8±16.38	53.4±14.34	1.49	0.141
4	Height	167.8±8.55	156.09±8.66	5.77	0.000
5	Weight	73.58±10.73	62.64±11.04	4.26	0.000
6	BMI	26.3±4.64	25.7±4.06	0.58	0.561
7	BSA DuBois	1.83±0.13	1.62±0.16	6.11	0.000
8	lt 1,36	7.12±5.7	5.94±5.1	0.93	0.358
9	lt 2,27	2.35±2.57	2.42±3.03	-0.13	0.898
10	FMi%	22.16±6.46	29.85±7.37	-5.09	0.000
11	FM kg	16.5±6.39	19.07±6.8	-1,65	0.103
12	Extracellular water, %	43.38±3.06	44.84±6.68	-1,19.	0.239
13	Extracellular water, kg	31.9±5.07	28±5.8	3.04	0.003
14	Cellular mass, %	37.05±5.32	32.2±4.93	4.39	0.000
15	Cellular mass, kg	27.2±5.31	20.2±4.7	5.92	0.000
16	Residual diuresis	523±650	452±528	0.51	0.613
17	Urine creatinine	32.2±30	55.2±36.13	.-2.94	0.005
18	Urine nitrogen	115.4±109.25	229.1±132.3	-2.66	0.011

Table II - Comparison of available data in males versus females

Variables		Male data	Female data	Statistics	
n.		Mean±SD	Mean±SD	T value	P value
19	Urine proteins	0.37±0.48	1.29±1.54	-3.42	0.001
20	Creatinemia	10.8±2.43	9.15±1.88	3.22	0.002
21	**BUN**	**75.4±20.8**	**70.9±18.22**	**0.98**	**0.332**
22	Total proteinemia	7.06±0.69	6.24±0.99	4.08	0.000
23	**Albuminemia**	**3.92±0.47**	**4.08±0.81**	**-1.03**	**0.310**
24	Cholesterolemia	218.9±39.5	268±53.4	-4.42	0.000
25	**Triglycerides**	**200.24±87.1**	**175.94±45.6**	**1.19**	**0.237**
26	**Hemoglobinemia**	**9.72±2.16**	**9.6±1.42**	**0.28**	**0.782**
27	**Hematocrit**	**29.27±6.92**	**28.7±4.12**	**0.42**	**0.673**
28	Transferrine	206.18±33.2	225.9±42.1	-2.21	0.031
29	**Lymphocytes**	**1972.6±973.2**	**1806.9±510.2**	**0.90**	**0.370**
30	**C3**	**89.98±18.72**	**93.75±20.2**	**-0.82**	**0.414**
31	**IgG**	**1064.5±228.3**	**961.8±134**	**1.88**	**0.064**
32	**Dialyzed V**	**12738±5896**	**12913±6559**	**-0.12**	**0.906**
33	**Dialysis glucose**	**916.5±405.4**	**863.6±434.3**	**0.53**	**0.595**
34	**Dialysis urea**	**60.4±28**	**53.6±20.06**	**1.18**	**0.241**
35	**Dialysis creatinine**	**6.19±3.09**	**5.22±2.05**	**1.57**	**0.122**

36	**Dialysis proteins**	**0,30±0,21**	**0.26±0.2**	**0.83**	**0.411**

Tables I and II show that males and females do not differ in measurements for age, body structure (BMI), glucose concentrations in dialysis solutions, and fat mass (kg)., However, fat mass calculated as percentage of weight is significantly higher in females, which is an expected difference due to the female body structure. No significant differences were observed for many metabolic and nutritional variables, such as, BUN, albuminemia, triglycerides, hemoglobinemia, hematocrit, lymphocytes, C3, and IgG. Furthermore, no significant differences were observed for all data concerning the dialytic treatment, this clearly related to the similarity of age and BMI. Comparison of data from males and females resulted in significant differences in cholesterolemia, which was greater in females, and for total protidemia and transferrine, which was lower in females. Additionally, resistance and reactance was greater in females, which is related to the fact that females have a greater amount of body water (see below).For residual renal function, the saved diuresis is not significantly different in males versus females, but its efficacy may be considered greater in females based on the significant differences in the urinary contents of creatinine and nitrogen. Based on the data presented above, it may be assumed that many basal general conditions are quite similar between males and females, with a relevant exception for body water composition, based on the ratio of extracellular water (kg) per cellular mass (kg). The results show a significantly greater ratio for extracellular water in females with respect to the lean mass; T value = -2,66, p = 0,011. This explains the significantly greater resistance and reactance in females and the significantly lower proteinemia, probably due to a greater protein dilution. Age and dialysis volume do not differ between males and females, while cellular mass (kg) strongly differs by gender, as expected. Indexing data in males and in females, the cellular mass and the dialysis volume by age, and the regressions of normalized cellular mass versus normalized dialysis volume resulted in significant results. In males, R = 0.509, R^2 = 0.259, and p = 0.037, while in females, R = 0.373, R^2 = 0.139, and p = 0.036. This shows that the dialysis volume was correctly adjusted to the body lean mass according to age. All of the following tables concern the relationships of BIA resistance and reactance with the available somatic data and with the treatment data, studied in different configurations. Scores were attributed to the degrees of correlations, similar to other previous publications. This method aims to calculate a numerical comparison of the results of different correlations. The scale of the scores is arbitrarily defined according to the p values, and as follows: p > 0.05 = 0, p between 0.049 and 0. 01 = 3, p between 0. 001 and 0.009 = 5, p equal to or lower than 0,0001 = 7. The mean and the standard deviations of the scores are calculated and the statistical comparison of the scores of different tables is performed using the T test. All the statistical calculations in this paper are operated by means of the statistical software Minitab 18, by MiNITAB, PE, USA.

Resistance and Reactance

In Tables III and IV, the abbreviations RST and RCT stand for Resistance and Reactance, respectively. The negative correlations indicate that the correlations between predicting variables and responding variables have negative values, that is, in the case of the negative correlations with resistance, an increasing value of resistance corresponds to a decreasing value of a correlated variable. For instance, in females, the increasing resistance is inversely correlated with cellular mass (kg), i.e., the lower the cellular mass, the greater the resistance to the electric current. Comparing data from males and females shows that they do not significantly differ in resistance and reactance correlations based on the following scores: T test value = 1.09 and p value =0,287 for males, and T test value = 0.45 and p value = 0.670 for females. Comparing the number of correlations with resistance and with reactance (resistance: males 1–16 and females 1–8; reactance: males 1–5 and females 1-5), we found no significant difference exists between males and females in the number of correlations; resistance T test = 2,03, p value = 0,059, and reactance 5 versus 5 with a difference = 0. Tables III, IV, V-A, V-B, and VI show the positive and negative correlations with resistance and reactance.

Table III - Male variables positively and negatively correlated with resistance and with reactance and ordered according to the correlation size

Positive correlations with resistance			
Resistance correlated variables	Pearson correlations	p value	RST scores
Reactance	0.546	0.023	3
Lymphocytes	0.598	0.011	3
Glucose dialysis concentration 1,36	0.731	0.001	5
		Mean	3.67
		SD	1.15
Table III - Negative correlations with resistance			
rResistance correlated variables	Pearson correlations	p value	RST scores

BMI	-0.691	0.002	5
Excreted urea	-0.666	0.003	5
BUN	-0.622	0.008	5
Weight	-0.582	0.014	3
Excreted proteins	-0.534	0.027	3
Excreted creatinine	-0.507	0.038	3
Cellular mass (%)	-0.501	0.04	3
Table III - negative correlations with resistance – following data			
Extracellular water (kg)	-0.496	0.043	3
		Mean	3.75
		SD	1.035
Positive correlations with reactance			
rReactance correlated variables	Pearson correlations	p value	RCT scores
Height	0.554	0.021	3
Negative correlations with reactance			
Weight	-0.526	0.03	3
rResistance correlated variables	-0.67	0.003	5

Table IV - Female variables positively and negatively correlated with resistance and with reactance and ordered according to the correlation size

Positive correlations with resistance			
Resistance correlated variables	Pearson correlations	p value	RST scores
Dialyzed solution glucose	0,361	0,042	3
Glucose dialysis concentration 1,36	0,389	0,028	3
Cholesterolemia	0,407	0,021	3
Reactance	0,473	0,006	5
Positive correlations with resistance – following data			
		Mean	3.5
		SD	1
Negative correlations with resistance			
Resistance correlated variables	Pearson correlations	p value	RST scores
Extracellular water (kg)	-0,494	0,004	5
Cellular mass (kg)	-0,417	0,018	3
Dialyzed solution creatinine	-0,376	0,034	3
Extracellular water (%)	-0,357	0,045	3
		Mean	3.5
		SD	1
Positive correlations with reactance			
Reactance correlated variables	Pearson correlations	p value	RCT scores
Cholesterolemia	0.352	0.048	3
Cellular mass (% of weight)	0.451	0.01	3
Resistance	0.473	0.006	5
Negative correlations with reactance			
Reactance correlated variables	Pearson correlations	p value	RCT

			scores
Extracellular water (% of weight)	-0.872	0.000	7
Females - negative correlations with reactance			
Extracellular water (kg)	-0.559	0.001	5

Table V A - Variables correlated with resistance in males and in females

	Males		Females		RST scores
Variables	Pearson correlations	p value	Pearson correlations	p value	Scores
Reactance	0.546	0.023	0,473	0.006	5
Extracellular water (kg)	-0.496	0.043	-0.494	0.004	5
mass (kg)	-0.809	0.000	-0.417	0.018	3
				mean	4.33
				SD	5

Table V B - Variables correlated with reactance in males and in females

	Males		Females		RCT scores
Variables	Pearson correlations	p value	Pearson correlations	p value	
Extracellular water (kg)	-0.689	0.002	-0.559	0.001	5

A statistical comparison of the scores in tTable V A and V B is impossible.

Table VI - Variables resulting in significant differences between males and females on the base of resistance values greater than the average value

	Males		Females		Statistics		
Variables	Mean	SD	Mean	SD	T Value	p value	Scores
Resistance	548.67	73.95	638.3	78.87	-2.72	0.014	3
Height	171.89	7.98	154.15	10,27007	4.57	0.000	7
BSA Bois	1.828	0.114	1.59	0.185	3.87	0.001	5
FMi%	24.87	7.38	32.56	9.16	-2.17	0.043	3
Urine nitrogen	24.25	3.80	18.65	5.64	2.78	0.012	3

Table VI - Variables resulting in significant differences between males and females on the basis of resistance values greater than the average value- following data

On the basis of resistance values greater than the average value	0.554	0.58	1.1	0.410	-2.45	0.029	3
Total proteinemia	7.073	0.78	6.18	1.066	2.26	0.036	3
Cholesterolemia	210.11	37.52	287.9	57.83	-3.83	0.001	5
						Mean	4
						SD	1.51

Table VI A - Variables resulting in significant differences between males and females on the basis of resistance values lower than the average value

	Males		Females		Statistics		
Variables	Mean	SD	Mean	SD	T Value	P value	Scores
Resistance	439.9	65.57	511	40.16	-2.91	0.013	3
Reactance	40.78	3.87	49.47	11.5	-2.53	0.023	3
Age	65.78	10.22	56.58	9.17	2.16	0.046	3
Height	165.11	7.15	157.4	7.34	2.46	0.025	3
Weight	80	10.6	63.21	10.62	3.65	0.002	5
Table VI B - Variables resulting in significant differences between males and females on the basis of resistance values lower than the average values							
BMI	29.34	3.46	25.47	3.68	2.51	0.022	3
BSA Du Bois	1.87	0.146	1.63	0.151	3.54	0.003	5
Extracellular water (kg)	35.51	4.28	29.15	5.67	2.99	0.008	5
Cellular mass (kg)	29053	5.87	21.28	3.74	3.51	0.004	5
Total proteinemia	7.1	0.808	6.28	0.96	2.16	0.044	3
Mean and SD of data in Tables VII A and VII B						Mean	3.8
						SD	1.033

The statistical comparison of the scores, that is to say the comparison of the degree of correlation between the data selected on the basis of the average value of resistance, for both values that were greater or lower than the average, shows no significant difference between the correlations, with a T value = 0.32, and a p value = 0.755.

Tables VII and VIII show the reactance data that is greater than the mean value. Table VIII shows the data with significant differences between males and females, and Tables IX and X show the data without significant differences.

Table VII - Comparison of male and female data related to reactance values greater than the mean value. Data shown are significantly different in males versus females

	9 males		14 females		Statistics		
Variables	Mean	SD	Mean	SD	T value	P value	Scores
Height	170.9	9.42	157	9.46	3.45	0.003	5
BSA Du Bois	1.77	0.077	1.62	0.18	2.75	0.013	3
Fat mass %	21.91	5.54	30.31	7.62	-3.06	0.006	5
Urine nitrogen	105.21	94.18	267.27	153.8	-3.13	0.005	5
Urine proteins	0.394	0.565	1.023	0.47	-2,78	0.015	3
Cholesterol	217.62	36.15	274.67	51.37	-3.12	0.005	5
Transferrin	198.25	21.3	227.28	36.05	-2.43	0.025	3
						Mean	4.14
						SD	1.07

Table VIII - Comparison of male and female data related to reactance values greater than the mean value. Data shown are not significantly different in males versus females

	9 males		14 females		Statistics	
Variables	Mean	SD	Mean	SD	T value	P value
Resistance	542.5	84.24	586	74.2	-2.27	0.225
Reactance	55.6	6.7	60.44	5.9	-1.77	0.097
Age	51	19.02	52.06	18.47	-0.13	0.897

Weight	66.36	4.68	62.53	11.91	1.08	0.294

Table IX - Comparison of male and female data related to reactance values greater than the mean value. Data shown are not significantly different in males versus females

	9 males		14 females		Statistics	
Variables	Mean	SD	Mean	SD	T value	P value
BMI	22.94	3.27	25.32	4.17	-1.53	0.142
Dialysis solutions liters 1.36	10	6.76	7.61	4.75	0.92	0.372
Dialysis solutions liters 2.27	1.5	2.33	1.47	2.45	0.03	0.977
Fat mass (kg)	14.62	4.21	19.35	7.15	-2	0.06
Extracellular water (%)	42.06	2.65	41.22	3.15	0.69	0.500
Extracellular water (kg)	27.84	1.52	25.8	5.44	1.32	0.205
Cellular mass (%)	37.85	5.63	34.74	4.17	1.42	0.178
Cellular mass (kg)	25.12	3.97	21.68	4.57	1.91	0.072
Residual diuresis	612.5	587.2	414.44	551	0.81	0.431
Urine Creatinine	32	30.40	63.38	44.42	-2,05	0.054

Table IX - Comparison of male and female data related to reactance values greater than the mean value. Data shown are not significantly different in males versus females – following data

Creatininemia	10.16	1.43	9.25	2	1.27	0.118
					Mean	0.308
					SD	0.290

Table IX - Comparison of male and female data related to reactance values greater than the mean value. Data shown are not significantly different in males versus females – following data

	9 males		14 females		Statistics	
Variables	Mean	SD	Mean	SD	T value	P value
BUN	68.84	18.97	74.78	17.98	-0.75	0.465
Albuminemia	4.11	0.514	4.1	0.901	0.03	0.973
Triglycerides	175.87	95.9	180.7	48.12	-0.14	0.891
Hemoglobin	9.45	1.53	9.96	1.52	-0.78	0.445
Hematocrit	28.9	3.91	28.22	3.99	0.42	0.683
Lymphocytes	2241.88	1155	1759.5	558.7	1.17	0.270
C3	91.17	18.65	89.45	21.42	0.20	0.841
IgG	1031	268.3	978.9	109.6	0.55	0.593
Dialyzed volume	14556	6241.8	13398	6789	0.42	0.680
Glucose	1042	492.5	947.8	467.38	0.51	0.617
Urea	49.12	26.56	55.94	23.6	-0.63	0.540
Creatinine	5.02	2.46	4.93	1.6	0.10	0.924
Proteins	0.19	0.146	0.201	0.141	-0.18	0.860
					Mean	0.676
					SD	0.214

The comparison of Tables VII, VIII, IX, and X was not based on the score values. All the data in Tables IX and X have scores = 0 because comparing male versus female data and founding no significance, therefore, the scores were not reported in the tables, and their comparison was based on T values. To maintain consistency, the comparison with Table VII that had scores, the analysis was similarly based on comparing T values. The comparison was based on running a

two samples T test, and resulted in the following: 1) T values of Table VII versus Tables VIII and IX, T value = 7. 78, p = 0.000; 2) T values of tTable VIIII versus Table IX, T value = 16.16, p = 0.000;and 3) T values of Table IX versus Table X, T value = 4.18, p = 0.000. Comparing the means and the standard deviations of the p values of Tables IX and X, and considering them together as a single table, resulted in less differences in males versus females than in Table X (0.308±0.290 for Table IX + X versus 676±0.214 for Table X; T value = - 3.91, p = 0.001).

It is of interest to note that the items of the two coupled tables concern two different subjects. Table X includes 13 variables, of which 10 variables (76,9%) concern body conditions and indirectly nutrition, and they were BUN, albuminemia, triglycerides, hemoglobin, hematocrit, lymphocytes, C3, IgG, excreted creatinine and proteins. Tables IX and X together present 24 variables, of which 10 (41,67%) concern directly or indirectly the body's water composition and are resistance, reactance, body weight, BMI, dialysis solutions, extracellular water in % of weight, extracellular water in kg, cellular mass %, cellular mass in kg, and residual diuresis. The results above show that the data in Table X fundamentally concerning the general conditions do not differ in males and females. The items shown in Tables VIII and IX are more similar in males versus females, particularly for reactance, fat mass (kg), cellular mass (kg), and urinary creatinine levels with p values of 0.097 (Table VIII), 0.06, 0.072, and 0.054 (Table IX), respectively.

The size of the variables in Tables IX and X was generally greater for males, even though it was not significant in 7 variables out of 11 in Table IX (63,64%) and 8 out of 13 in Table X (61,54%). The prevalence in males was seen in the following variables: weight (Table VIII), dialysis solutions, extracellular water, and cellular mass (as percentage of weight and as kg), residual diuresis and creatininemia (Table IX). In Table X, the prevalence for males was seen in the following variables: albuminemia, hematocrit, lymphocytes, C3, IgG, dialyzed volume, and excreted creatinine. The prevalence for females was observed in: BUN, hemoglobin, triglycerides, urea, and excreted proteins in dialyzed solutions. Comparing the data in Table IX with the data in Table X by using the T test, we found that the difference of similarities between males and females is statistically significant, with a T value = -3.85 and a p value = 0.001.

Tables XI and XII respectively show the scores of correlations with resistance and with reactance values greater or lower than their average values, as well as the comparison of the correlations scores of resistance and reactance values in males versus females , males versus males, and females versus females.

Table XI - Males and females - Total of scores concerning the correlations with resistance and with reactance values greater and lower than the average values

Males		
Scores of the correlations		Sum of scores
Resistance > average value		17
Resistance < average value		19
Reactance > average value		22
Reactance < average value		3
	Mean	15.25
	SD	8.42

Table XI - Females

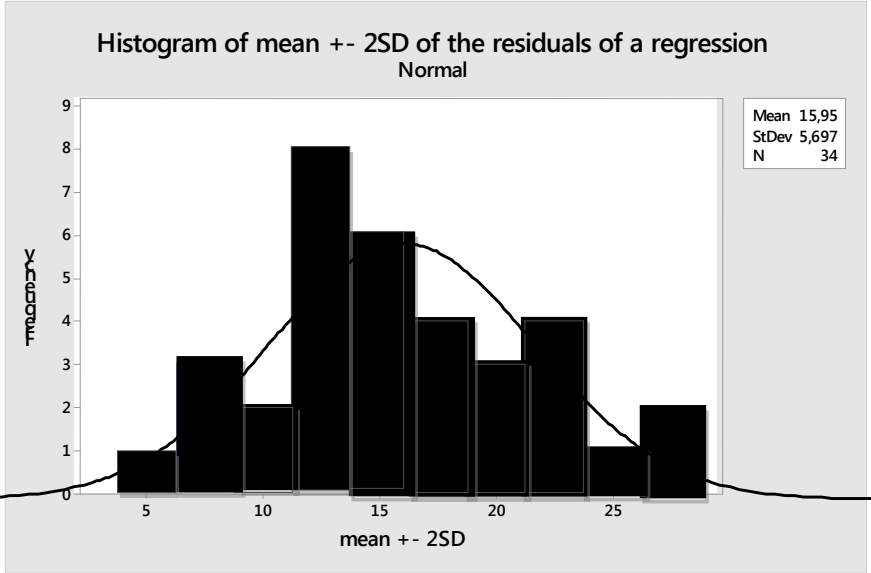
Scores of the correlations		Sum of scores
Table XI – Females – data		
Resistance > average value		3
Resistance < average value		15
Reactance > average value		5
Reactance < average value		16
	Mean	9.75
	SD	6.71

Table XI : the statistical comparison by T test of scores in males versus females resulted in non significance; T value = 1.11 and p value = 0.316.

Table XII - Comparison of correlations scores with resistance and reactance values by their means and standard deviations in males versus females , males versus males, and females versus females

Scores of the correlations	Mean±SD	n.	Resistance	
Males Resistance	4±1,35	12	T value	p value
Females Resistance	3,75±1,49	8	0,38	0,709
	Mean±SD	n.	Reactance	
Males Reactance	4,2±1,095	5	T value	p value
Females Reactance	5±1,63	4	3,75±1,49	8
Males Resistance	4±1,35	12	T value	p value
Males Reactance	4,2±1,095	5	-0,32	0,756
Females Resistance	3,75±1,49	8	T value	p value
Females Reactance	5±1,63	4	-1,29	0,254

In Table XI, no differences in the scores resulted from comparing males and females for resistance and reactance values greater or lower than the average values. The same result was observed in Table XII comparing the correlations scores concerning resistance and reactance in males versus males, females versus females and males versus females. In other words, all the consistent correlations did not differ. The analysis of correlations shows the existence of both a significant or no significant relationship between two variables, in the case comparing between resistance and reactance, and between resistance or reactance versus other variables. However, the statistical correlation, per se, is not suitable to point out in depth the degree of similarity between the predicting variables and the predicted variables, that is diversely completely defined by the size of residuals by regressing a variable versus the hypothesized correlated variable. Applying this method, it is possible to know if resistance and reactance are suitable to adequately predict the size of the variables resulting in significant correlations. For this aim, it was assumed that resistance and reactance could attain this target if the range of the residuals of the regressions, mean + 2SD, and mean – 2SD, evaluated as actual residuals and as absolute residuals should be equal or lower to 10% of the size of the predicted variables, where the absolute residuals are the values of the root square of the square actual residuals. The consistent results are shown in Tables XII, XII, XIII, XIV, and XV for males, and in Tables XVI, XVII, XVIII, and XIX for females. In the tables, the residuals having a mean + 2SD greater than 10% or a mean - 2SD greater than -10% are emphasized in bold characters. The limits for a correct prediction are stated in residuals comprised between their means ± two standard deviations, because this range includes by default 98% of the values of an item's distribution as shown in the following graph reporting the values of the residuals of a regression assumed as an example.



The graph shows the data distributed in bars of different shapes, based on the frequencies of very similar data, forming groups that are graphically represented as bars. The shape of the slope shows the normal distribution of all the known items within 98%, with the theoretical remaining +1% and - 1% being assumed due to the values of possibly unknown further data.

Males

Table XII - 17 Males - variables regressed versus resistance	
Reactance	Weight

R	R2	p	R	R2	P
0.546	0.298	0.0233	0.582	0.339	0.014
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.57	4.3	0.131	0.716	6.95	0.103
Mean + 2SD	9.17		Mean + 2SD	**14.62**	
Mean - 2 SD	-8.03		Mean - 2 SD	**-13.18**	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
3	3.035	0.99	5.21	4.47	1.16
Mean + 2SD	9.07		Mean + 2SD	**14.15**	
Mean - 2 SD	-3.07		Mean - 2 SD	-3.73	

Table XIII- 17 Males - variables regressed versus resistance

BMI			Liters of dialysis solution 1,36%		
R	R2	P	R	R2	P
0.691	0.448	0.0021	0.731	0.534	0.00086
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.106	0.92	0.114	0.143	0.347	0.414
Mean + 2SD	1.95		Mean + 2SD	0.837	
Mean - 2 SD	-1.73		Mean - 2 SD	-0.551	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.724	0.56	1.3	0.227	0.29	0.766
Mean + 2SD	1.84		Mean + 2SD	0.807	
Mean - 2 SD	-0.396		Mean - 2 SD	-0.353	

Table XIV - 17 Males - variables regressed versus resistance

Cellular mass (kg)			Blood urea nitrogen		
R	R2	p	R	R2	P
0.809	0.654	8.46*e^-0.5	0.622	0.387	0.0078
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.092	0.9	0.102	2.5	10.97	0.227
Mean + 2SD	1.89		Mean + 2SD	**24.44**	
Mean - 2 SD	-1.71		Mean - 2 SD	**-19.44**	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.692	0.56	1.235	9.31	5.91	1.57
Mean + 2SD	1.81		Mean + 2SD	**21.13**	
Mean - 2 SD	-0.428		Mean - 2 SD	-2.51	

Table XV - 17 Males - variables regressed versus resistance

Lymphocytes	Excreted urea

R	R2	p	R	R2	p
0.598	0.357	0.011	0.666	0.444	0.0035
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
117.1	53.1	2.2	4.09	12.9	0.317
Mean + 2SD	**223.3**		Mean + 2SD	**29.89**	
Mean - 2 SD	**10.9**		Mean - 2 SD	**-21.71**	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
(-17.08	53.1	-0.322	9.79	9.09	1.08
Mean + 2SD	**89.12**		Mean + 2SD	**27.97**	
Mean - 2 SD	**-123.28**		Mean - 2 SD	**-8.39**	
Mean - 2 SD	**10.9**		Mean - 2 SD	**-21.71**	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
data					
-17.08	53.1	-0.322	9.79	9.09	1.08
Mean + 2SD	**89.12**		Mean + 2SD	**27.97**	
Mean - 2 SD	**-123.28**		Mean - 2 SD	**-8.39**	

Females

Table XVI -32 Females - variables regressed versus resistance					
Reactance			Dialysis solution 1.36%		
R	R2	p	R	R2	p
0.473	0.224	0.0062	0.389	0.152	0.027
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.936	5.28	5.64	0.214	0.437	2.039
Mean + 2SD	**11.496**		Mean + 2SD	1,088	
Mean - 2 SD	**-9.264**		Mean - 2SD	-0,66	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
4.26	3.17	0.743	0.268	0.405	1.51
Mean + 2SD	**10.6**		Mean + 2SD	1.078	
Mean - 2 SD	**-2.08**		Mean - 2 SD	-0.542	

Table XVII - 32 Females - variables regressed versus resistance					
Extracellular water (%)			Extracellular water (kg)		
R	R2	p	R	R2	P
0.357	0.128	0.045	0.494	0.244	0.004
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.378	0.39	8.99	0.246	1.366	5.56
Mean + 2SD	1,158		Mean + 2SD	2.978	
Mean - 2SD	-2,012		Mean - 2SD	-2.486	

2.04	2.71	1.33	1.01	0.82	0.746
Mean + 2SD	7.46		Mean + 2SD	2.65	
Mean - 2 SD	-3.38		Mean - 2 SD	-0.63	

Table XVIII - 32 Females - variables regressed versus resistance					
Cholesterolemia			Cellular mass (kg)		
R	R2	P	R	R2	P
0.407	0.166	0.021	0.417	0.174	0.018
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
23.02	139.1	6.04	0.178	0.91	5.12
Mean + 2SD	**301.22**		Mean + 2SD	1.998	
Mean - 2SD	**-225.2**		Mean - 2SD	-1.642	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
106.84	90.03	0.843	0.676	0.62	0.916
Mean + 2SD	**286.9**		Mean + 2SD	1.916	
Mean - 2 SD	**-73.22**		Mean - 2 SD	-0.564	

Table XIX - 32 Females - variables regressed versus resistance					
Dialyzed glucose solutions			Dialyzed creatinine		
R	R2	p	R	R2	p
0.361	0.13	0.042	0.376	0.141	0.034
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
13.96	5.34	0.38	0.035	0.114	3.25
Mean + 2SD	**210.1**		Mean + 2SD	0,263	
Mean - 2SD	**26.78**		Mean - 2SD	-0,193	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
3482	4375.8	1.26	0.086	0.082	0.953
Mean + 2SD	**24.65**		Mean + 2SD	0.25	
Mean - 2 SD	**3.28**		Mean - 2 SD	-0.078	

From the tables above, the results show that for males, resistance is able to predict, according to the assumed correct percentage of residuals, the following: reactance, BMI, the liters of dialysis solutions with 1,36% of glucose, and cellular mass (kg). While the percentage residuals overcoming the correct percentage residuals concerned weight, blood urea nitrogen, and excreted urea. In females, the correct prediction of regressions on resistance of percentage residuals concerned the liters of dialysis solutions with 1,36% of glucose, the extracellular water %, the extracellular water mass in kg, and cellular mass in kg. The residuals overcoming the correct percentage resulted in the following: reactance, cholesterolemia, and dialyzed glucose solution. The regressions concerning males attained four correct predictions, and three erroneous results. The regressions concerning females attained the same number of correct and incorrect results as in males. Tables XXX, XXI, and XXII show the results of regressions versus reactance for males and Tables XXIII and XXIV show the results of the consistent regressions for females.

Table XX - 17 Males - variables regressed versus reactance					
Age			Height		
R	R2	p	R	R2	p
0.671	0.449	0.0032	0,..54	0.307	0.021

Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
1.39	6.82	0.204	0.48	12.1	0.039
Mean + 2SD	**18.96**		Mean + 2SD	**24.68**	
Mean - 2 SD	**-12.25**		Mean - 2 SD	**-23.72**	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
5.33	4.29	1.24	10.37	5.69	1.82
Mean + 2SD	**13.91**		Mean + 2SD	**21.75**	
Mean - 2 SD	-3.25		Mean - 2 SD	-1.01	

Table XXI- 17 Males - variables regressed versus reactance

Weight			BMI			Extracellular water (kg)		
R	R2	p	R	R2	P	R	R2	p
0.526	0.277	0.03	0.7	0.49	0.0018	0.689	0.475	0.0022
Actual residuals (%)			Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.78	7.01	0.112	0.103	0.93	0.111	0.127	1.22	0.104
Mean + 2SD	**14.8**		Mean + 2SD	1.963		Mean + 2SD	0.099	
Mean - 2 SD	**-13.24**		Mean - 2 SD	-1.757		Mean - 2 SD	-2.313	
Absolute residuals (%)			Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
5.32	4.43	1.21	0.667	0.638	1.05	1.02	0.64	1.59
Mean + 2SD	**14.18**		Mean + 2SD	1.943		Mean + 2SD	2.3	
Mean - 2 SD	**-3.54**		Mean - 2 SD	-0.609		Mean - 2 SD	-0.26	

Table XXII - 17 Males - variables regressed versus reactance

Table XXIII - Females - variables regressed versus reactance

Extracellular water (% of weight)			Extracellular water (kg)		
R	R2	p	R	R2	P
0.872	0.76	8.387*E-11	0.559	0.313	0.0009
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.104	1.69	16.26	0.27	1.33	4.91
Mean + 2SD	3.484		Mean + 2SD	2.93	
Mean - 2 SD	-3.276		Mean - 2 SD	-2.39	
Mean + 2SD	3.5		Mean + 2SD	2.63	
Mean - 2 SD	-1.06		Mean - 2 SD	-0.41	
Absolute residuals (%)			Absolute residuals (%)		

Absolute residuals (%) – following data					
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
1.22	1.14	0.934	1.11	0.76	0.686

Table XXIV - Females - variables regressed versus reactance					
Cellular mass (% of weight)			Cholesterolemia		
R	R2	p	R	R2	P
0.451	0.204	0.0096	0.352	0.124	0.048
Actual residuals (%)			Actual residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
0.224	1.33	5.97	0.188	1.30	6.92
Mean + 2SD	2.884		Mean + 2SD	2.788	
Mean - 2 SD	-2.436		Mean - 2 SD	-2.412	
Absolute residuals (%)			Absolute residuals (%)		
Mean	SD	Coeff. Var.	Mean	SD	Coeff. Var.
1.11	0.745	0.672	1.049	0.765	0.73
Mean + 2SD	2.6		Mean + 2SD	2.579	
Mean - 2 SD	-0.38		Mean - 2 SD	-0.481	

Evaluation of the results of the regressions versus reactance

Males - the variables attaining percentage residuals comprised in means ± 2 standard deviations lower than 10% for actual and absolute residuals are BMI, and extracellular water (kg)., In fact, they reached lower than 5%, while age, height, and weight overcame the correct limits.

Females – all the considered variables have percentage residuals inside the means ± 2 SD, were lower than 5%, with the same variables observed in males inside the correct limits.

It is important to note that males have correct residuals in two out of five variables (40%), while females have correct residuals for all the variables (100%).

Observing the results for the regressions versus resistance, males have correct residuals in four out seven (57.14%) variables, with females exhibiting the same pattern. Considering the results above comprehensively, the regressions concerning the female data exhibited better results that the male data. This observation is confirmed by comparing, in males versus females, the coefficients of variation of the actual and absolute percentage residuals of the regressions, whose results are shown in Tables XXVI, XXVII, XXVIII, and XXIX.

Table XXVI - Comparison in males versus females of coefficients of variation of actual residuals % concerning the regressions versus resistance					
	Males	Females	Test		
Mean	0.452	4.63	Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$	
SD	0.717	2.67	Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$	
Statistics			T value	DF	p value
			-3.91	8	0.005

Table XXVII - Comparison in males versus females of coefficients of variation of absolute residuals % concerning the regressions versus resistance					
	Males	Females	Test		
Mean	0.973	0.998	Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$	
SD	0.574	0.276	Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$	
Statistics			T value	DF	p value
			-0,12	10	0,91

Table XXVIII - Comparison in males versus females of coefficients of variation of actual residuals % concerning the regressions versus reactance

	Males	Females	Test		
Mean	0.114	8.51	Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$	
SD	0.059	5.23	Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$	
Statistics			T value	DF	p value
			-3.21	3	0,049

TABLE XXIX- Comparison in males versus females of coefficients of variation of absolute residuals % concerning the regressions versus reactance

	Males	Females	Test		
Mean	1.38	0.755	Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$	
SD	0.316	0.121	Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$	
Statistics			T value	DF	p value
			4,06	5	0,01

The tables show that the coefficients of variation are greater in females in three out of four tables, in two out of three tables, while only in Table XXIX are the coefficients greater in males. The coefficients of variation measure the variability of the size of a series of items; therefore, in the series of residuals of a regression, it measures the degree of power of a regression to adequately follow in predicting the regressed variable. In practical terms, this confirms the better performance of female regressions.

Final general consideration and conclusions.

The study presented here may be considered in two different parts: the first concerning the description of the basal data for males and females and their comparison, and the second concerning the different aspects of the relationships between resistance and reactance and the 37 considered basal variables. No differences were observed between males and females comparing age and body structure, i.e., BMI and fat mass (kg), the latter resulting in significantly greater numbers in females as percentage of weight due the basic anatomical female structure. However, it has to be emphasized that the following metabolic and nutritional variables also did not differ: BUN, albuminemia, triglycerides, hemoglobinemia, hematocrit, lymphocytes, C3, and IgG. Similarly, all the data concerning the dialytic treatment did not differ as well, possibly as a consequence of the similarity in age and BMI. The evaluation of the correlations existing between the BIA resistance and BIA reactance and of BIA resistance and BIA reactance versus the variables concerning the bodily conditions showed that males and females do not significantly differ in a number of correlations. Additionally, no differences were observed between the data selected on the basis of the average value of resistance, and whether it was greater or lower than the average. Based on the inherent insufficiency of the correlation test to fully state the correspondence between each item of the correlating variable with the correlated variable, we opted to use the linear regression method, specifically regressing the correlated variables versus the correlating variables. Using this method, the degree of the exactness of correspondence between predicting variables and predicted variables was appreciated by the size of the residuals, and it was assumed to be adequate if it did not overcome the means ± 2 standard deviation of the actual and absolute values of the residuals. The difference of the results between males and females was relevant, because males attained this target only for BMI and extracellular water (kg) (40% of the considered variables), while the female regressions attained the target for all the considered variables (100%). The very different result between males and females is probably based on the great difference in the number of items between males and females, leading to a greater variance of the predictions in female regression, which in turn led to a degree of significant difference in males versus females for the following variables: resistance, reactance, triglycerides, and IgG. Of particular interest, the number of items are included in Tables XXX, XXXI, XXXII, XXXIII, and XXXIV, and show the difference of variances.

Table XXX - Difference of variance of the reported variables between males and females

Resistance	Mean ± SD	Statistics	Coeff. Var.
17 males	488.2±89.67	T value = -2.86	0.184
36 females	562.7±85.9	p = 0,008	0.153
Difference of variance			
Bonett's Test			
p value	0.018		

Levene's Test		
p value	0.081	

Table XXXI - Difference of variance of the reported variables between males and females

Reactance	Mean ± SD	Statistics	Coeff. Var.
17 males	47.76±9.24	T value = -1.87	0.193
36 females	53.22±11.16	p = 0,069	0.21
Difference of variance			
Bonett's Test			
p value	0.000		
Levene's Test			
p value	0.001		

Table XXXII - Difference of variance of the reported variables between males and females

Triglycerides	Mean ± SD	Statistics	Coeff. Var.
17 males	200±87	T value = 1.07	0.435
36 females	175.9±45.6	p = 0.295	0.259
Difference of variance			
Bonett's Test			
p value	0.004		
Levene's Test			
p value	0.000		

Table XXXIII - Difference of variance of the reported variables between males and females

IgG	Mean±SD	Statistics	Coeff. Var.
17 males	1064±228	T value = 1.71	0.214
36 females	961.8±134	p = 0.101	0.139
Difference of variance			
Bonett's Test			
p value	0.013		
Levene's Test			
p value	0.044		

Table XXIV - Difference of variance of the reported variables bs between males and females

Number of items	Mean±SD	Statistics	Coeff. Var.
17 males	9±5.05	T value = -3.78	0.561
36 females	16.5±9.38	p = 0.000	0.568
Difference of variance			
Bonett's Test			
p value	0.001		

Levene's Test	
p value	0.004

The evaluation of the results of the regressions versus resistance and versus reactance : showed that both males and females attained residuals lower than the targeted 10%, lower than 5%; however, it has to be emphasized that the regressions versus resistance and versus reactance of the 37 considered variables for males and females resulted in significant poor prevalence. We observed a resistance of 21,62% for males and females, a reactance of 13.51% for males and 10.81% for females. Based on the results of the regressions, it is possible to note that the variables significantly correlated to resistance in males were reactance, weight, BMI, dialysis solutions 1,36%, cellular mass (kg), BUN , lymphocytes, and urea. For females, the variables were: reactance, dialysis solutions 1,36%, extracellular water %, extracellular water (kg), cholesterolemia, cellular mass (kg), dialyzed glucose solution, and dialyzed creatinine. The variables correlated with reactance resulted for males in the following categories: age, height, weight, BMI, extracellular water (kg). While for females, they resulted in the following categories: extracellular water (% of weight), extracellular water (kg), cellular mass (% of weight), and cholesterolemia. Taking into account that the variables correlated with resistance and with reactance are the variables on which the sizes of resistance and of reactance are based, it is possible to note that they differ between males and females. Neglecting the constant relationship between resistance and reactance for males and for females, resistance for males is fundamentally based on variables concerning the dry body components and their biologic byproduct (BUN, urea), while in females, it goes beyond the dry body components, and widely include the variables concerning the body water composition. Reactance for males is based on physical parameters and on extracellular water, while for females it is based on body water. The same variable concerning the cellular mass is defined as percentage of weight, that is to say as the proportion of the weight with respect to body water and fat. Therefore, resistance and reactance based on body measures differ between males and females. For males, they are fundamentally based on body basal measures and on dry tissue measures, while in females, they are fundamentally based on body water content. BIA measures should be evaluated differently between males and females, even when having similar values, because they are differently based.

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