Bioelectrical Impedance Analysis (BIA) For Assessing Tbw and Ffm of Indian Females

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ABSTRACT

Background: *The Bioelectrical Impedance analysis is an easy, applicable method for assessing Total Body water and Fat Free Mass of various groups of people. It has many advantages over other methods and is safe, rapid, portable, easy to perform and require minimum operator training. It has been used extensively for developing specific prediction equation for different ethnicity, age, gender, level of body fatness and physical activity. Regression equations play great role to estimate the body density and fatness specific to the owing to methodological and biological factors.*

Purpose: *The purpose of the study was to investigate the utility of multi-frequency BIA for the estimation of TBW and FFM of Indian females at different frequencies. Earlier scientists have measured various parameters of body composition of Indian population using MALTRON-II. However, literature shows that prediction equations have not been developed for Indian females which could develop the heathy prediction equation for Indian females (unhealthy eating habits). It has been found in the study that women particularly Indian womens have unhealthy eating habits owing to the fact that they concentrate only on 1 aspect was their food cooked good enough to eat, but they don't understand the meaning of healthy food. In the present research paper, an attempt has been made to develop BIA equations using data taken from PhD thesis (1). This data was taken from my senior Dr. Goswami, who collected the data in the college in which he was teaching. Some of the data that my supervisor, co-supervisor and myself has taken in DRDO have already been utilized in building multi-compartmental model, developing generalized age and sex specific prediction equation and developing REE of Indian subjects.*

Keywords: R(2.9.2) software, Bio Electrical Impedance Analysis, Prediction Equation, MALTRON-II, Multiple Regression Analysis, Total Body Water, Fat Free Mass, Impedance index.

Methods: Data of reference (1) included vital information about body composition of 60 Indian females such as age, TBW, FFM, height, weight, impedance and phase at 5KHz., 50KHz., 100KHz. and 200 KHz.. This data was then used to calculate the impedance index i.e. (height^2/impedance) at the respective frequencies. This method uses multiple regression analysis to drive prediction equation of Indian females at frequencies of 5KHz.,50KHz.,100KHz.,200KHz., As we Know that in multiple regression analysis wherein the main aim is to predict dependent variable from the no. of independent variables that are known which is called dependent variable from 1 or more independent variable also called as predictor variable. One more theme in developing prediction equation of Here in this study we used TBW and FFM as dependent variable and Weight of females and Impedance index i.e.(height^2/impedance) as independent variable at different frequencies of 5 KHz.,50KHz.,100KHz.,200KHz respectively. Data was fed then into R software, an integrated suite of software facilities used for data manipulation, calculation and graphical display. It is used for effective data handling and storage facility. The main use of R software is for regression analysis, which was then used to generate the prediction equation. The prediction developed here is through multiple regression analysis. In multiple regression analysis the equation is of the form given below;
$Y=m_1x_1+ m_2x_2+ m_3x_3+..........+m_nx_n+ c$; where c is intercept and $m_1,m_2,m_3.....m_n$ are the weight's assigned to each of the predictor variables by the regression solution.

Result: Data used in commercial software provided 8 BIA equations; 4 for TBW and 4 for FFM at frequencies of 5 KHz, 50KHz, 100 KHZ and 200 KHz. And so 8 sets of dependent variable were there, This data included other statistical data such as mean, standard deviation and correlation of Total Body Water (TBW) and Fat Free Mass(FFM) with Impedance index and Weight. Besides this scatter matrix plot for Total Body Water (TBW) and Fat free Mass (FFM) ,Normal distribution of standardised residuals showing the relationship between TBW and FFM ,Scale location plot, Residual verses leverage plot, standardised residual verses cook's distance plot at frequencies of 5 KHz,50KHz,100 KHZ and 200 KHz are plotted. These plots for linear model objects give the diagnostic information about the linear model.

Conclusions: The final race-combined TBW prediction equations included stature^2/resistance and body weight. Multiple regression analysis was carried out on clinical data through R 2.9 software. The BIA prediction equation for Total Body water and Fat Free mass was developed at different frequencies of 5 KHz. and 50 KHz. respectively. The data was taken for Indian females lying in a limited age span of 17-22 years.

I. INTRODUCTION:

Developing prediction equation for Indian females for evaluating and monitoring growth and nutritional status is an important area of research. Assessing the body composition through isotope dilution, hydro densitometry, dual X-ray absorbtiometry (DXA),air displacement plethysmography, magnetic resonance imaging, are sometimes used for body composition analysis, but these equipments are not easily available and is expensive to maintain, so their use in clinical and field studies is limited. One of the most popular methods for body composition analysis is through Bioelectrical Impedance Analysis. One of the main advantages of using BIA method is that it does not require high technician skill, it is generally more comfortable and does not intrude much on client's privacy. Traditional BIA method which is still most frequently used involves the measurement of impedance at single frequency generally at 50KHz. Although single frequency BIA is most used in clinical practices, this device could not predict Total Body Water accurately. MF-BIA seems to give a better estimation of hydration than SF-BIA because the principle of measuring the flow of current through the body (impedance) is dependent on the frequency applied. At low frequencies, the current cannot bridge the cellular membrane and will pass predominantly through the extracellular space. At higher frequencies penetration of the cell membrane occurs and the current is conducted by both the extra-cellular water (ECW) and intra-cellular water (ICW).

In India when it comes to general health of people there is a large disparity between urban elite class and rural class. Obesity is becoming a factor in many nations around the world. According to latest obesity statistics, sponsored by International Day of Evaluation of Abdominal Obesity;75 percent of Indian women and 58 percent of Indian men are obese. Besides this, numerous studies indicate that malnutrition is another serious health concern that Indian women face (Chatterjee, 1990; Desai, 1994; The World Bank, 1996). It threatens their survival as well as that of their children. The negative effects of malnutrition among women are compounded by heavy work demands, by poverty, by childbearing and rearing, and by special nutritional needs of women, resulting in increased susceptibility to illness and consequent higher mortality. Attention, must therefore be paid to determine the body composition of females so that appropriate measures can be taken if women in India are facing abnormality in their health due to their abnormal nutritional status.

The purpose of the current study was to use the female body composition database to develop and predict TBW and FFM at the frequencies of 5KHz, 50KHz, 100KHz, 200KHz so that, a general idea about the health status of Indian female can be observed and for that purpose multiple regression analysis is done.

Subjects and Methods: Data of 60 Indian females from reference(1) was used to develop and predict TBW and FFM at 5KHz,50KHz,100KHz,200KHz which was then used for the descriptive analysis of Indian females which included their age, weight, height, Total Body Water(TBW), Fat Free Mass (FFM), and Impedance at these frequencies. These data were then used to calculate the body stature. i.e. (height^2/impedance) of females. In this paper, a powerful statistical program R (version 2.9.2); basically used for statistical analysis is used. Here we have used this software to develop linear model for Total Body Water(TBW) and Fat Free Mass(FFM) at different frequency and form a prediction equation using weight and Impedance index i.e. (height^2/impedance) of females at these frequencies as independent variables and TBW and FFM as dependent variables. The obtained equations are of the form:

$$TBW_{(f1,f2,f3,f4)}=a_0Wt.+a_1Z_{I(f1,f2,f3,f4)} +C_{1(f1,f2,f3,f4)} \qquad (1)$$

$$FFM_{(f1,f2,f3,f4)}=b_0Wt.+b_1Z_{I(f1,f2,f3,f4)} +C_{2(f1,f2,f3,f4)} \qquad (2)$$

Where $TBW_{(f1,f2,f3,f4)}$ and $FFM_{(f1,f2,f3,f4)}$ is Total Body Water and Fat Free Mass at frequencies f1=5KHz.,f2=50KHz.,f3=100KHz.,f4=200KHz. and $Z_{I(f1,f2,f3,f4)}$ is the calculated Impedance index i.e. (height^2/impedance) of females at these frequencies. $C_{1(f1,f2,f3,f4)}$ and $C_{2(f1,f2,f3,f4)}$ are intercepts of equation (1) and (2) respectively and a_0, b_0 are coefficients multiplied by weight variable of equation(1) and(2) respectively and a_1, b_1 are coefficients multiplied by Impedance index variable of equation(1) and(2) respectively. The flowchart showing the sequence of operations of algorithm used in R 2.9 software to develop and predict linear model of TBW, FFM at these multiple frequencies is also shown in Figure(1)

TABLE 1.

Clinical data of 60 Indian females from reference (1), showing age, weight, sex and customer ID of subjects

Serial no.	Customer Id	Weight(Kg)	Sex(Male)	Age(Years)
1.	187	44	1	17
2.	127	50	1	17
3.	173	45	1	17
4.	108	53	1	18
5.	140	46	1	18
6.	167	62	1	18
7.	169	52	1	18
8.	171	39	1	18
9	176	52	1	18
10.	183	57	1	18
11.	186	44	1	18
12.	188	51	1	18
13.	189	39	1	18
14.	190	43	1	18
15.	191	54	1	18
16.	192	50	1	18
17.	193	58	1	18
18.	203	40	1	18
19.	206	54	1	18
20.	195	57	1	18
21.	208	55	1	18
22.	207	51	1	19
23.	115	50	1	19
24.	163	56	1	19
25.	164	63	1	19
26.	165	48	1	19
27.	168	57	1	19
28.	170	45	1	19
29.	172	50	1	19
30.	177	56	1	19
31.	178	60	1	19
32.	181	51	1	19
33.	182	54	1	19
34.	184	60	1	19
35.	211	60	1	19
36.	212	61	1	19
37.	214	52	1	19
38.	201	52	1	19
39.	166	56	1	20
40.	194	47	1	21
41.	175	37	1	21
42.	180	52	1	22
43.	185	47	1	22
44.	209	53	1	22
45.	71	39	1	23
46.	179	50	1	23
47.	210	58	1	23
48.	54	41	1	24
49.	119	42	1	24
50.	220	45	1	25
51.	53	47	1	25
52.	51	54	1	26
53.	118	62	1	30
54.	124	48	1	30
55.	144	72	1	31
56.	162	55	1	32
57.	125	57	1	33
58.	174	56	1	37
59.	92	50	1	41
60.	197	77	1	42

TABLE 2.

Clinical data of 60 Indian females from reference(1) showing impedance and impedance index at frequencies of 5KHz.,50KHz.,100KHz.,200KHz.

S.No.	FFM(Kg)	TBW(Lt.)	Z at 5KHz.	Z at 50 KHz.	Z at 100 KHz.	Z at 200 KHz.	Z_I at 5KHz.	Z_I at 50 KHz.	Z_I at 100KHz.	Z_I at 200KHz.
1.	37.61	24.35	845	769	718	718	29.17	32.05	34.33	34.33
2.	38.38	26.22	793	692	654	619	29.135	33.387	35.327	37.32
3.	24.02	11.82	871	827	762	762	28.66	30.186	32.76	32.76
4.	43.27	27.79	861	766	725	692	31.33	36.41	38.47	40.31
5.	39.23	25.28	890	792	755	723	32.64	33.136	34.76	36.29
6.	45.91	30.19	804	731	682	682	35.104	38.61	41.384	41.384
7.	39.9	25.81	869	794	731	731	29.09	31.84	34.58	34.58
8.	34.87	23.27	843	761	723	723	28.499	31.57	34.518	33.229
9	38.31	25.39	890	816	757	757	26.99	29.44	31.737	31.737
10.	49.24	27.38	809	739	696	696	30.857	33.781	35.868	35.868
11.	36.7	23.06	954	873	846	846	26.167	28.59	29.508	29.508
12.	39.2	26.04	765	720	674	674	31.405	33.37	35.645	35.645
13.	33.54	21.64	936	872	819	819	24.634	26.495	28.21	28.21
14.	36.59	24.03	869	775	728	728	27.646	31	33.001	33.001
15.	39.86	25.73	853	804	760	760	29.266	31.05	32.8473	32.84736.8
16.	41.94	26.24	887	785	748	748	39.066	35.103	6.84	4
17.	40.56	27.16	881	793	723	723	28.335	31.48	34.53	34.53
18.	32.93	21.6	942	835	780	780	22.939	25.88	27.71	27.71
19.	38.4	25.22	884	838	786	786	27.177	28.669	30.566	30.566
20.	44.04	28.66	827	766	722	722	33.72	36.41	38.63	38.63
21.	39.88	25.85	891	821	774	774	28.02	30.41	32.25	32.25
22.	36.95	24.21	943	860	809	809	24.83	27.22	28.94	28.94
23.	40.89	25.93	953	839	798	763	28.56	32.45	34.117	35.68
24.	43.19	27.51	842	783	737	737	32.73	35.19	37.389	37.389
25.	43.77	29.13	828	743	707	707	32.088	35.76	37.58	37.58
26.	38.47	24.35	878	814	759	759	28.43	30.668	32.89	32.89
27.	39.25	27.25	792	723	681	681	29.56	32.37	34.37	34.37
28.	34.56	23.13	879	805	763	763	24.919	27.21	28.71	28.71
29.	39.88	26.08	822	764	725	725	30.755	33.09	34.87	34.87
30.	41.2	28.81	713	624	581	581	33.26228.	38.006	40.82	40.82
31.	40.13	27.62	865	766	724	724	134	31.77	33.613	33.613
32.	41.18	26.24	893	809	771	771	30.118	33.246	34.884	34.884
33.	40.16	26.62	829	770	717	717	30.113	32.42	34.817	34.817
34.	45.89	28.9	875	801	755	755	33.81	36.93	39.184	39.184
35.	44	28.3	868	783	740	740	31.75	35.193	37.24	37.24
36.	45.1	29.01	833	769	740	740	33.88	36.7	38.14	38.14
37.	41.25	25.35	1004	910	843	843	27.78	30.65	33.08	33.08
38.	39.17	25	850	857	810	810	29.74	29.49	31.21	31.21
39.	39.08	26.32	900	815	769	769	27.04	29.86	31.646	31.646
40.	37.06	23.51	983	911	851	851	25.39	27.402	29.335	29.335
41.	31.91	20.75	1100	1006	938	938	21.56	23.57	25.28	25.28
42.	37.91	25.85	833	761	717	717	28.102	30.76	32.648	32.648
43.	6.3	25.49	870	825	778	778	32.83	34.62	36.72	36.72
44.	12.33	25.99	873	808	765	765	30.06	32.48	34.305	34.305
45.	7.19	21.06	991	903	857	842	22.1	24.256	25.56	26.014
46.	12.34	25.74	803	712	668	668	28.772	32.45	34.586	34.586
47.	12.73	25.7	892	827	768	768	25.224	27.21	29.29	29.29
48.	5.29	23.07	932	842	803	804	27.812	30.785	32.28	32.24
49.	5.6	23.88	967	855	813	781	27.476	31.07	32.68	34.019
50.	16.6	25.96	966	876	819	819	22.98	25.34	27.104	27.104
51.	12.49	23.5	884	805	760	749	24.77	27.21	28.82	29.24
52.	13.66	26.21	920	829	785	775	28.526	31.65	33.43	33.43
53.	21.16	29.6	730	645	613	584	32.911	37.248	39.19	41.138
54.	10.66	26.25	800	666	626	592	28.88	34.69	36.91	39.03
55.	30.27	31.27	819	705	665	635	30.48	35.41	37.54	39.313
56.	16.6	25.96	816	745	702	702	30.59	33.51	35.56	35.56
57.	16.53	29.11	752	631	591	558	31.948	38.074	40.65	43.05
58.	15.82	27.61	803	743	691	691	31.88	34.45	30.18	37.05
59.	11.07	26.02	871	780	739	722	30.13	33.65	35.512	35.512
60.	36.2	32.48	708	639	605	605	34.815	38.57	40.74	40.74

Flowchart showing the general process carried to develop and predict TBW and FFM at different frequencies:

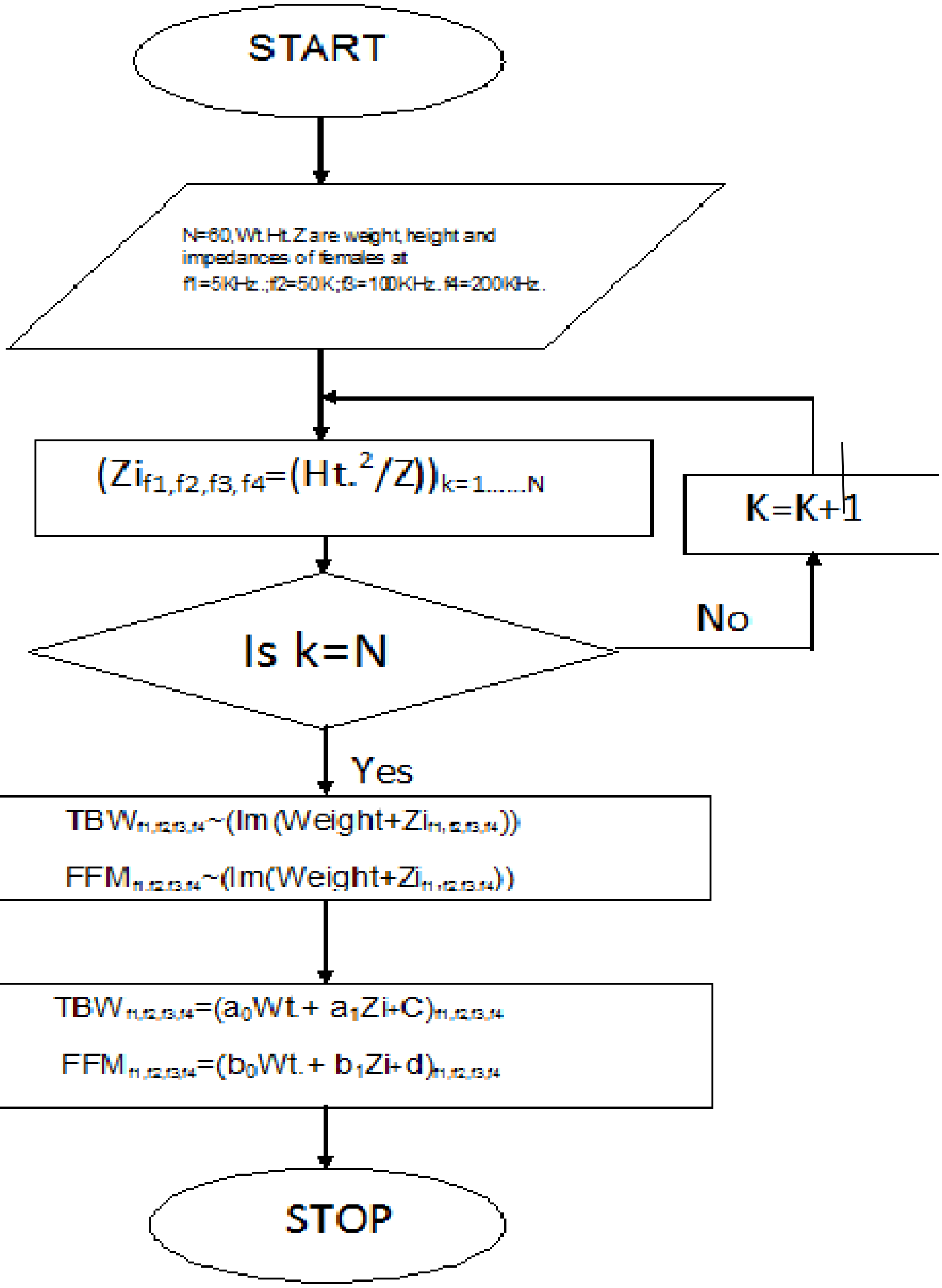


Fig1: Flowchart showing the general process to develop linear model of TBW and FFM at frequencies of 5KHz,50KHz,100KHz and 200KHz

Results and Statistical Analysis: The equation used to predict TBW and FFM were developed at the frequencies of 5KHz,50KHz,100KHz,200KHz.by using the data from table 1 and 2 .The table below show the predicted TBW and FFM equation at different frequencies and their statistical analysis:

TABLE 3.

S.No.	Prediction Equations developed	Frequency	Mean	Standard deviation	Standard error	Residual error	MultipleR^2	Adjusted R^2
1.	TBW=0.24689Wt.+0.25593Zi+5.58336	5KHz	TBW=25.8553 Wt.=51.9333 Zi=29.10972	TBW=3.093788 Wt.=7.717176 Zi=3.152058	Intercept = 2.24234 Wt.=0.04102 Zi=0.10042	1.845 on 57 df	0.6564	0.6444
2.	TBW=0.22363Wt.+0.9178Zi+4.89741	50KHz	TBW=25.8553 Wt.=51.9333 Zi=32.02492	TBW=3.093788 Wt.=7.717176 Zi=3.629973	Intercept=2.06674 Wt.=0.22363 Zi=0.08522	1.773 on 57 df	0.6826	0.6714
3.	TBW=0.23751Wt.+0.24204Zi+5.31032	100KHz	TBW=25.8553 Wt.=51.9333 Zi=33.921	TBW=3.093788 Wt.=7.717176 Zi=3.837306	Intercept=2.12356 Wt.=0.03996 Zi=0.8057	1.809 on 57 df	0.6696	0.658
4.	TBW=0.24689Wt.+0.25593Zi+5.58336	200KHz	TBW=25.8553 Wt.=51.9333 Zi=34.31884	TBW=3.093788 Wt.=7.717176 Zi=4.070613	Intercept=2.01648 Wt.=0.03921 Zi=0.07433	1.787 on 57 df	0.6776	0.6663
5.	FFM=0.12496Wt.+0.56707Zi+15.91914	5KHz	FFM=38.91633 Wt.=51.9333 Zi=29.10988	FFM=3.96432 Wt.=7.717176 Zi=3.152027	Intercept=3.7801 Wt.=0.06915 Zi=0.16929	3.11 on 57 df	0.4054	0.3845
6.	FFM=0.11924Wt.+0.50014Zi+16.70689	50KHz	FFM=38.91633 Wt.=51.9333 Zi=32.02492	FFM=3.96432 Wt.=7.717176 Zi=3.629973	Intercept=3.62533 Wt.=0.07032 Zi=0.14949	3.111 on 57 df	0.4051	0.3843
7.	FFM=0.1392Wt.+0.42686Zi+17.20422	100KHz	FFM=38.91633 Wt.=51.9333 Zi=33.92158	FFM=3.96432 Wt.=7.717176 Zi=3.827306	Intercept=3.70514 Wt.=0.06971 Zi=0.14057	3.157 on 57 df	0.3874	0.3659
8.	FFM=0.21844Wt.+0.34863Zi+15.78796	200KHz	FFM=39.109 Wt.=51.9333 Zi=34.35368	FFM=3.9268 Wt.=7.717176 Zi=4.160915	Intercept=3.05025 Wt.=0.06081 Zi=0.11278	2.752 on 57 df	0.5256	0.509

Graphical Analysis: The graphical interpretation of data include scatter matrix plot, Random scatter distribution, normal distribution, scale location plot, residual verses leverage plot and standardized residual verses cook's distance plot at different frequencies

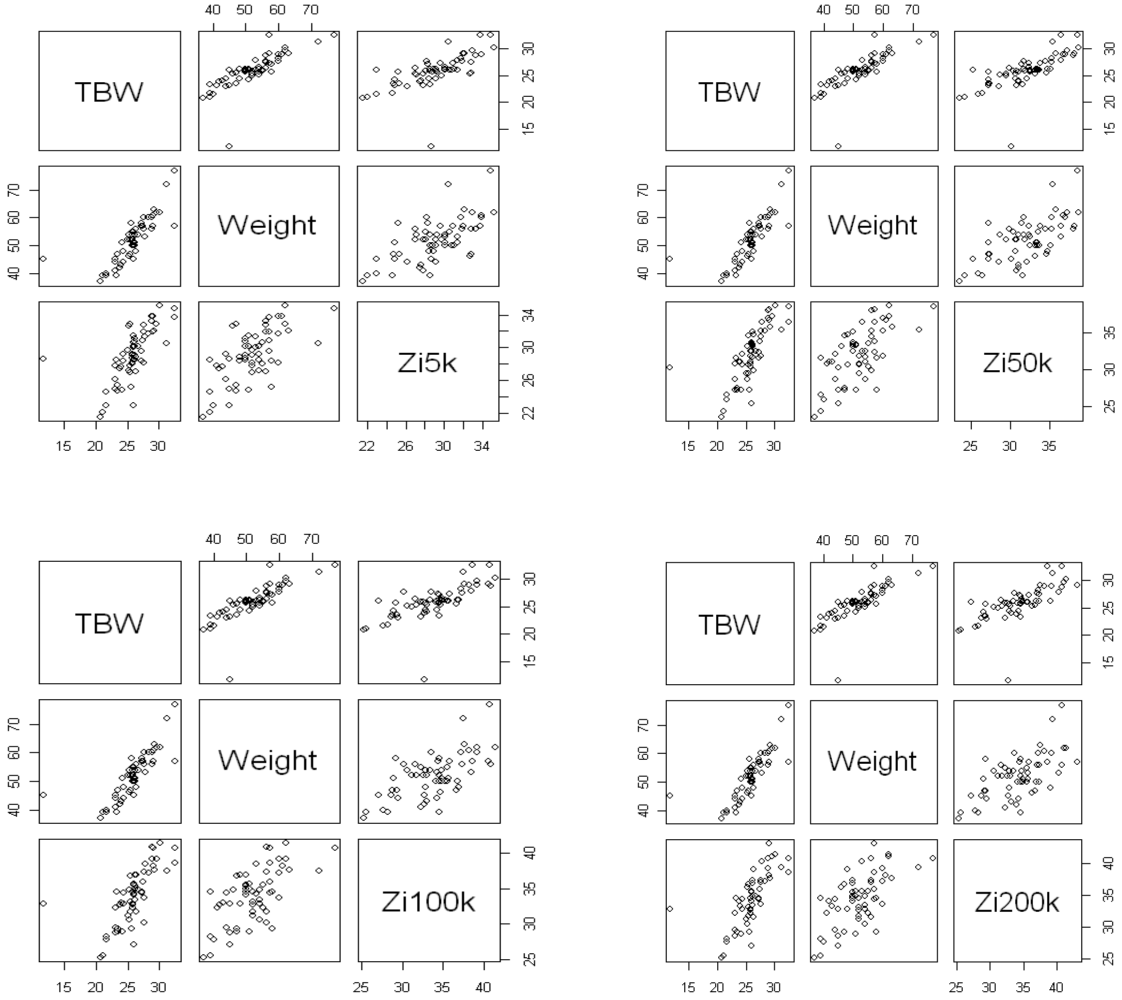


Fig.2: Scatter Plot Matrix distribution of body composition of Indian females showing the relationship between Total Body Water(TBW)in (litre) , Impedance Index ($Height^2$/Impedance of body at frequencies of 5KHz,50KHz,100KHz,200KHz)in (cm^2/Ω) and Weight of body in Kg.

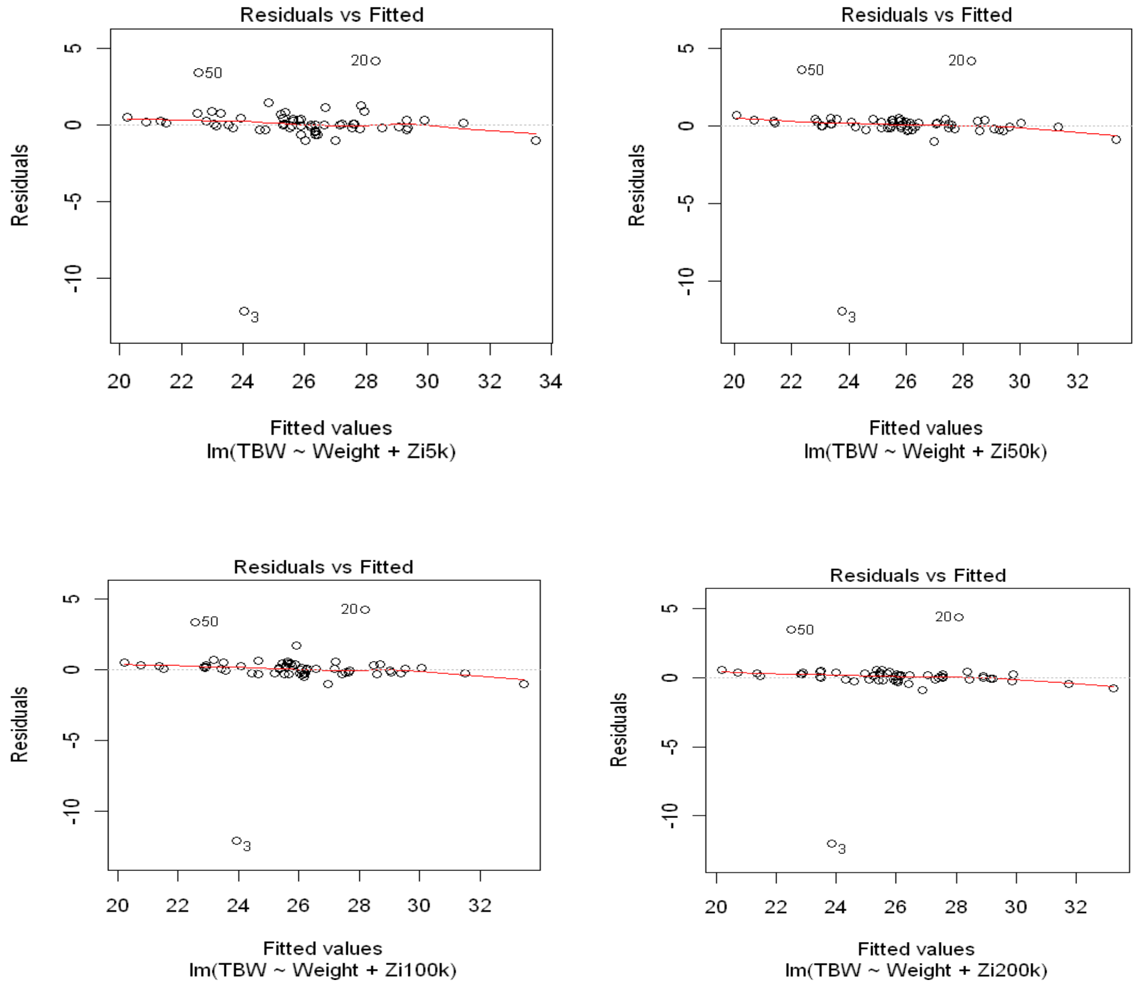


Fig3 : Random scatter distribution of residual versus fitted values of Indian males showing the relationship between Total Body Water(TBW)in (litre) , Impedance Index (Height^2/Impedance of body at 5KHz.frequency)in (cm^2/Ω) and Weight of body in Kg. at 5KHz.

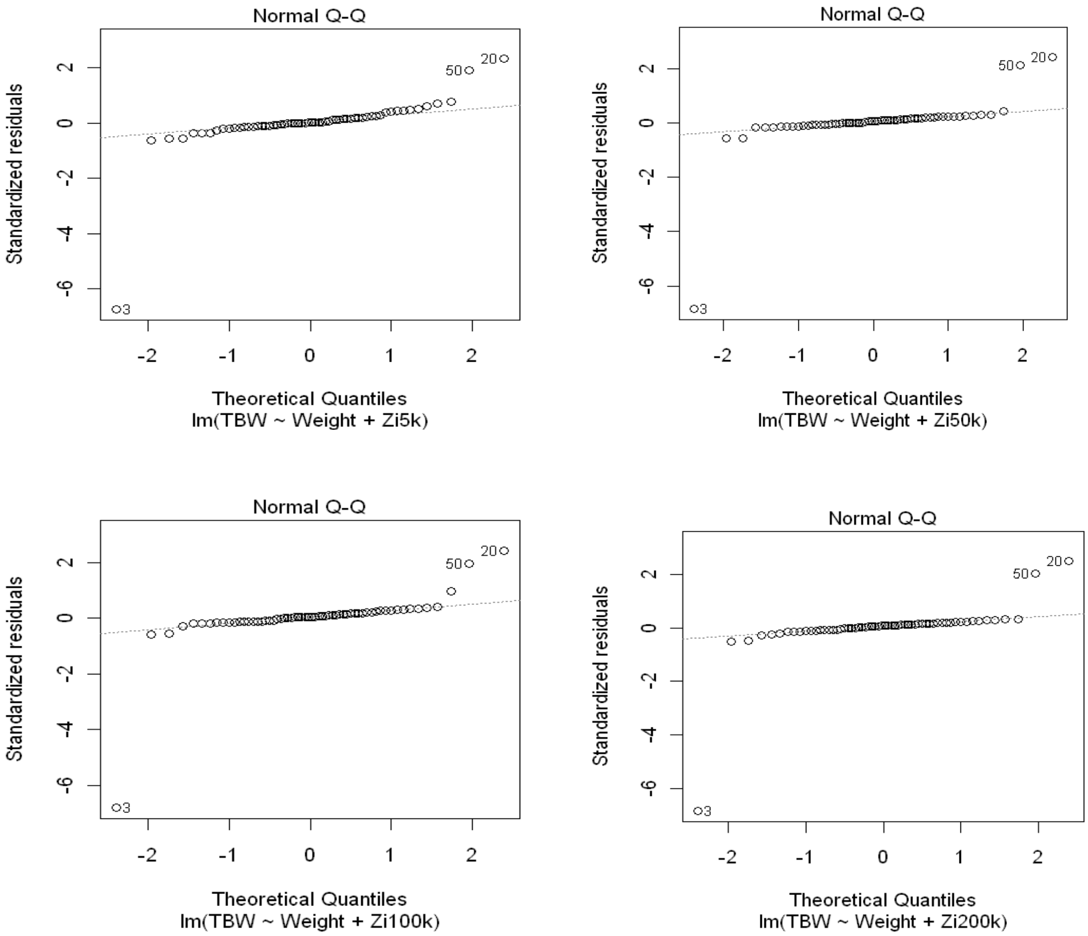


Fig.4: Normal distribution versus Standardized residuals of Indian females showing the relationship between Total Body Water(TBW)in (litre) , Impedance Index (Height^2/Impedance of body at frequencies of 5KHz.,50KHz.,100KHz.,200KHz.)in (cm^2/Ω) and Weight of body in Kg. at 5 KHz.

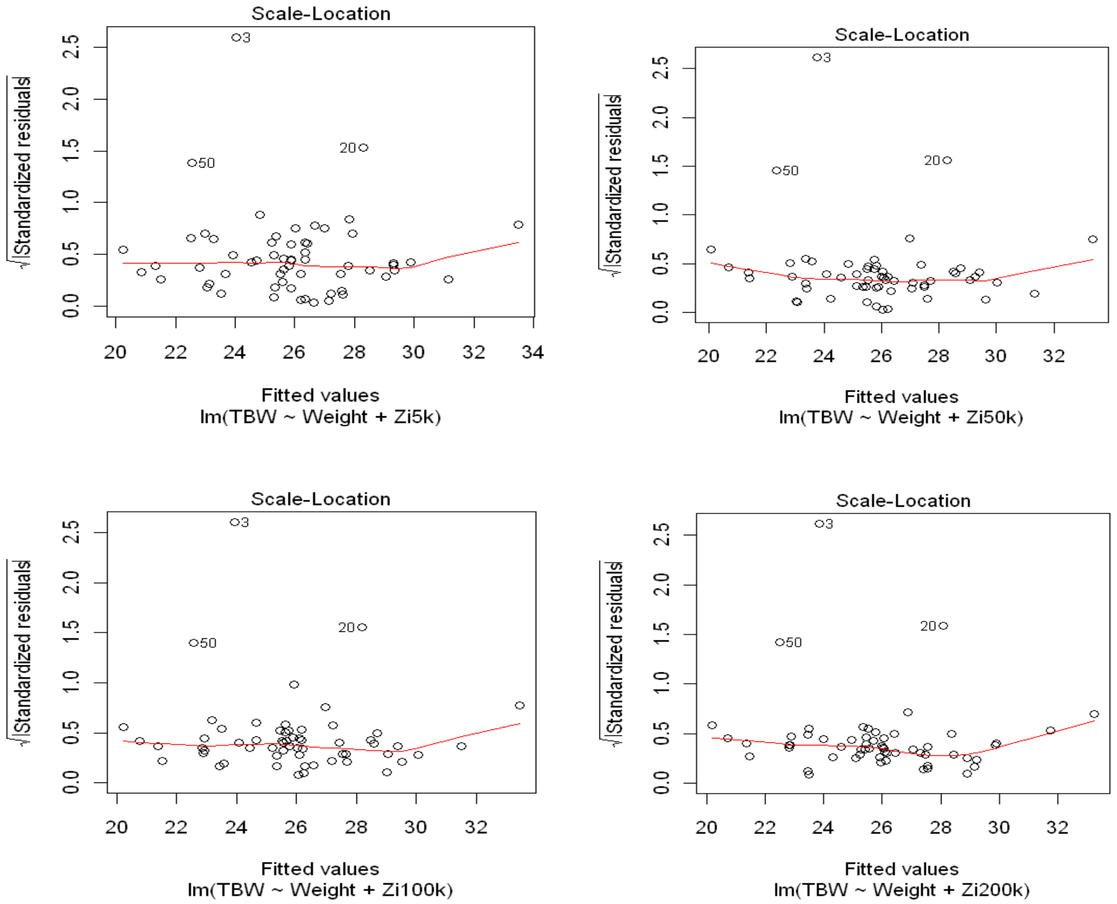
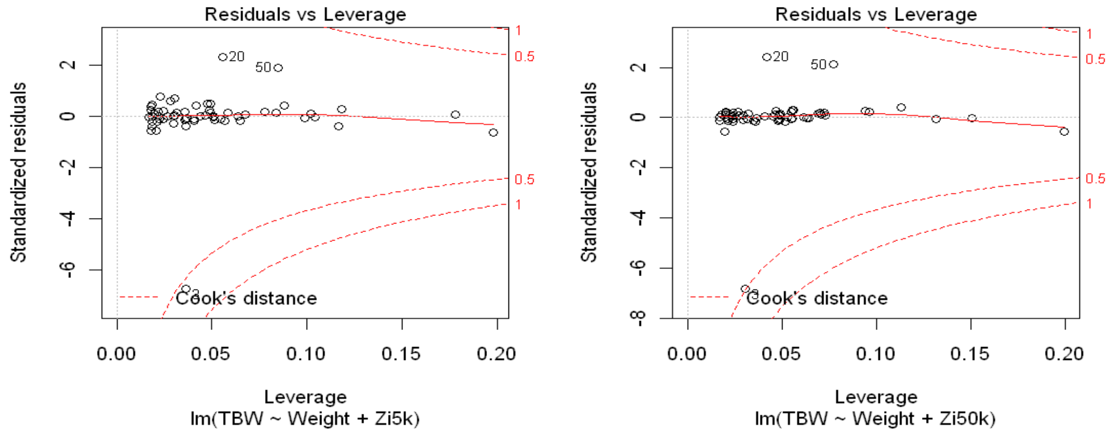


Fig5: Scale location plot between the square root of standardized residuals versus fitted values of Indian females showing the relationship between Total Body Water(TBW)in (litre) , Impedance Index (Height^2/Impedance of body at 5KHz,50KHz.,100KHz.,200KHz.frequencies)in (cm^2/Ω) and Weight of body in Kg.



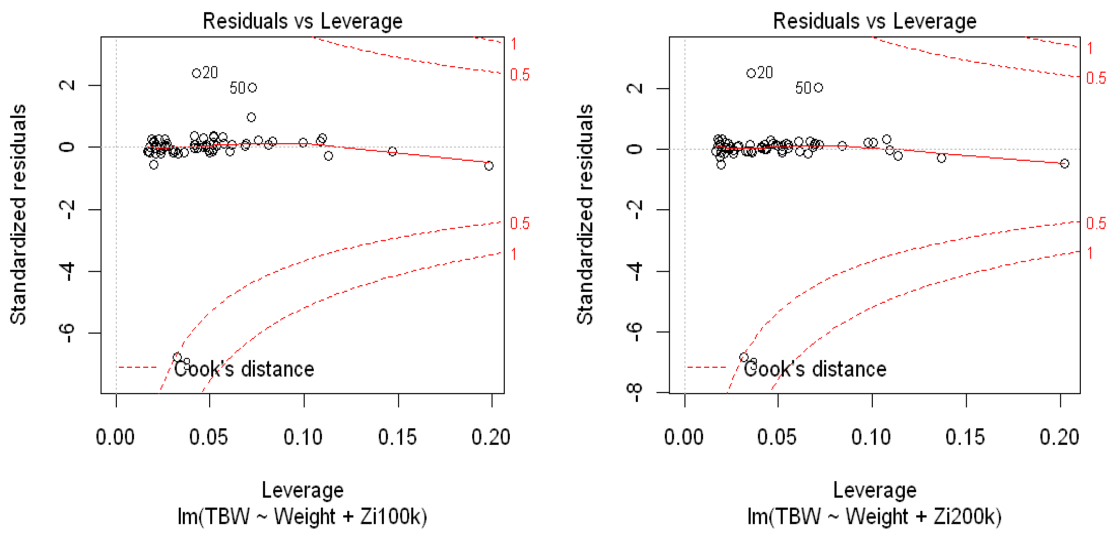


Fig6: Residual versus leverage plot and standardised residuals verses cook's distance plot of Indian females showing the relationship between Total Body Water(TBW)in (litre) , Impedance Index (Height^2/Impedance of body at 5KHz,50KHz,100KHz,200KHz.frequencies)in (cm^2/Ω) and Weight of body in Kg.

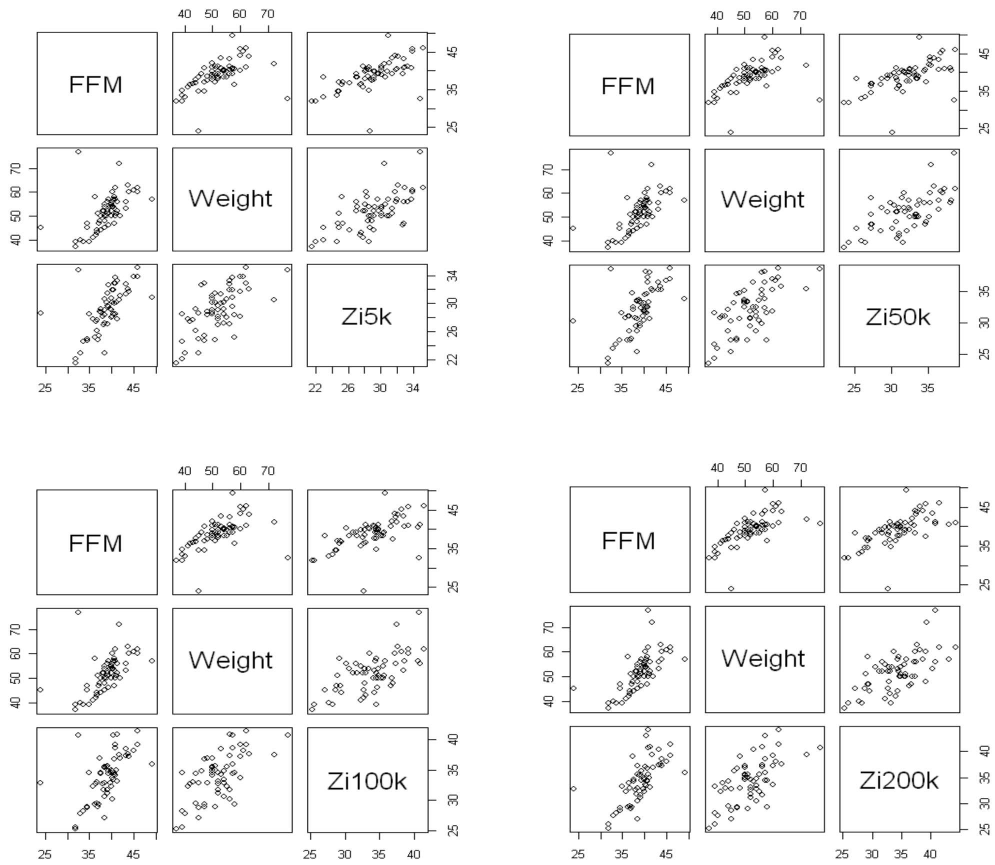


Fig7: Scatter Plot Matrix distribution of body composition of Indian females showing the relationship between Fat Free Mass(FFM)in Kg. , Impedance Index (Height^2/Impedance of body at 5KHz.,50KHz,100KHz,200KHzfrequencies) in (cm^2/Ω) and Weight of body.

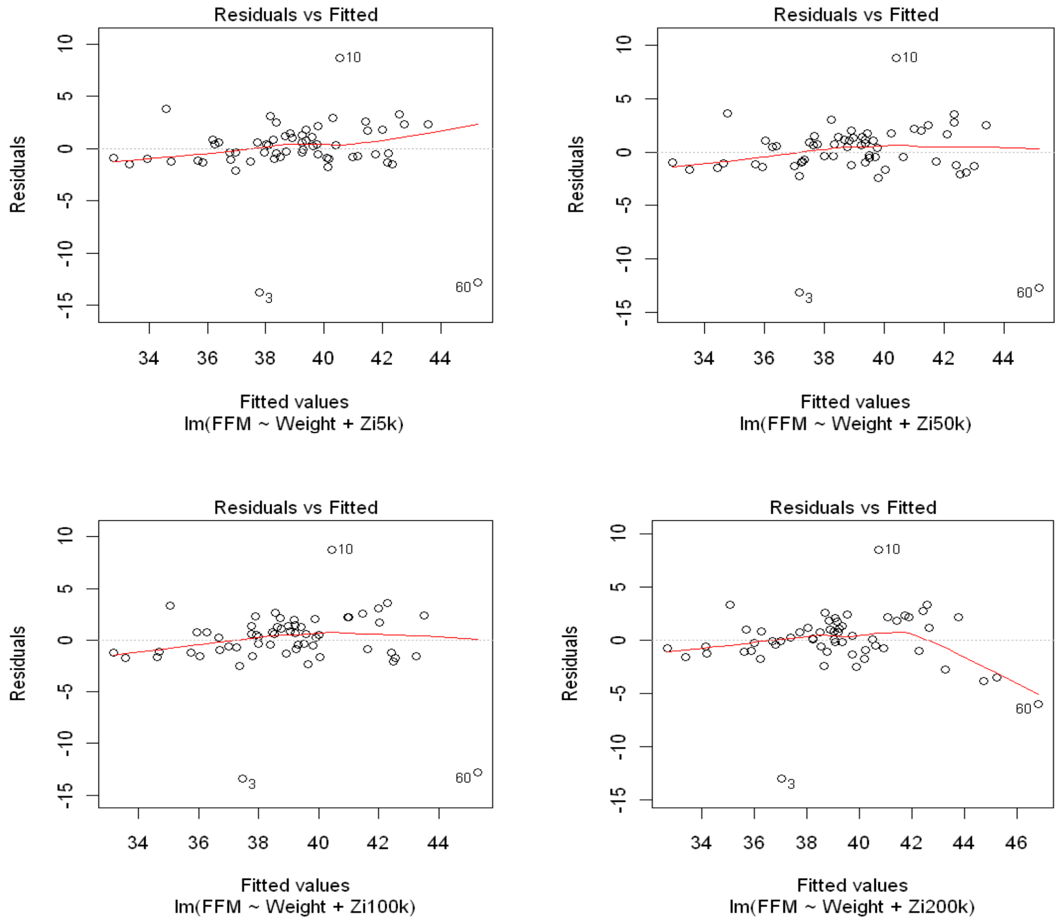
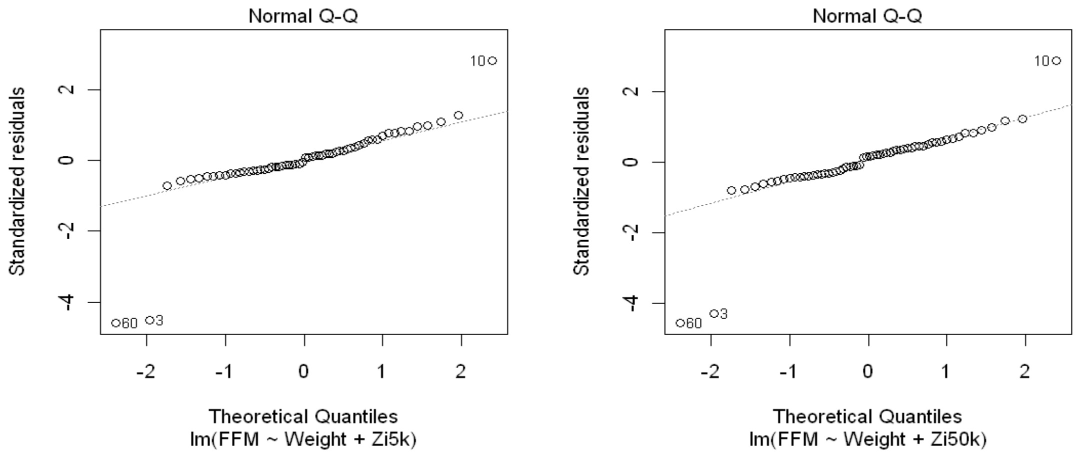


Fig 8: Random scatter distribution residual versus fitted values of Indian males showing the relationship between Fat Free Mass(FFM)in Kg. , Impedance Index (Height^2/Impedance of body at 5KHz,50KHz,100KHz,200KHz.frequencies) in (cm^2/Ω) and Weight of body in Kg.



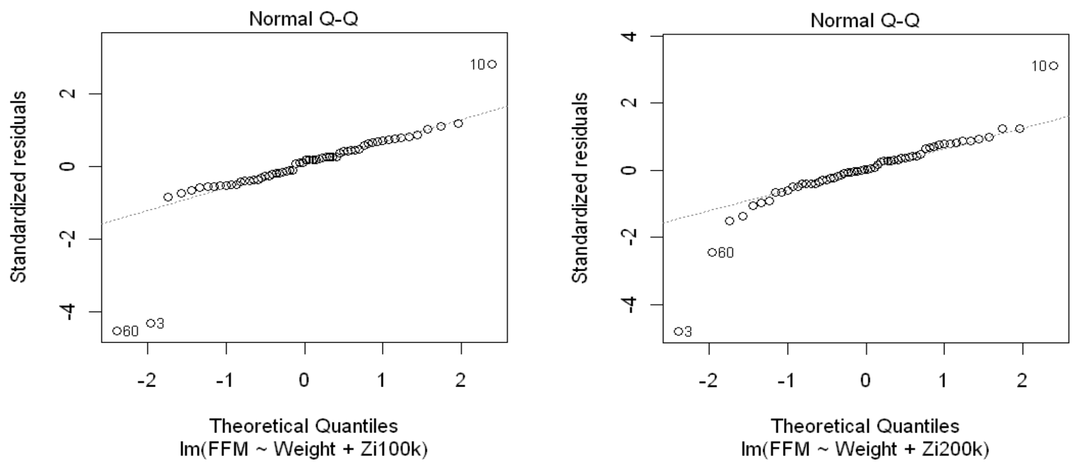
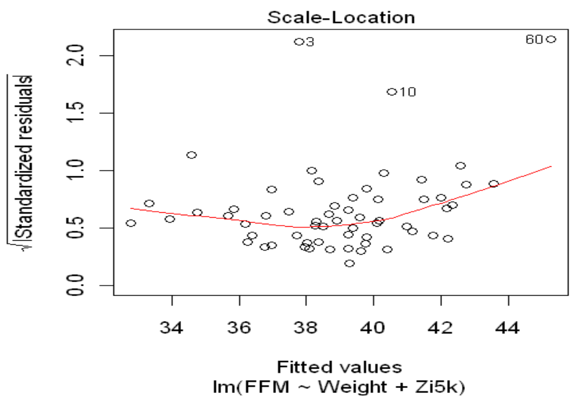
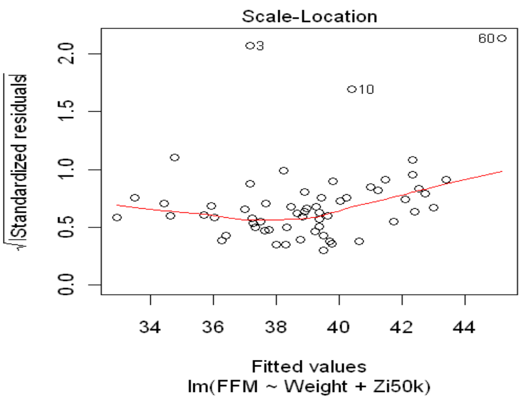


Fig9: Normal distribution versus Standardized residuals of Indian males showing the relationship between Fat Free Mass(FFM)in Kg. , Impedance Index (Height^2/Impedance of body at 5KHz,50KHz,100KHz,200KHzfrequencies) in (cm^2/Ω) and Weight of body in Kg.





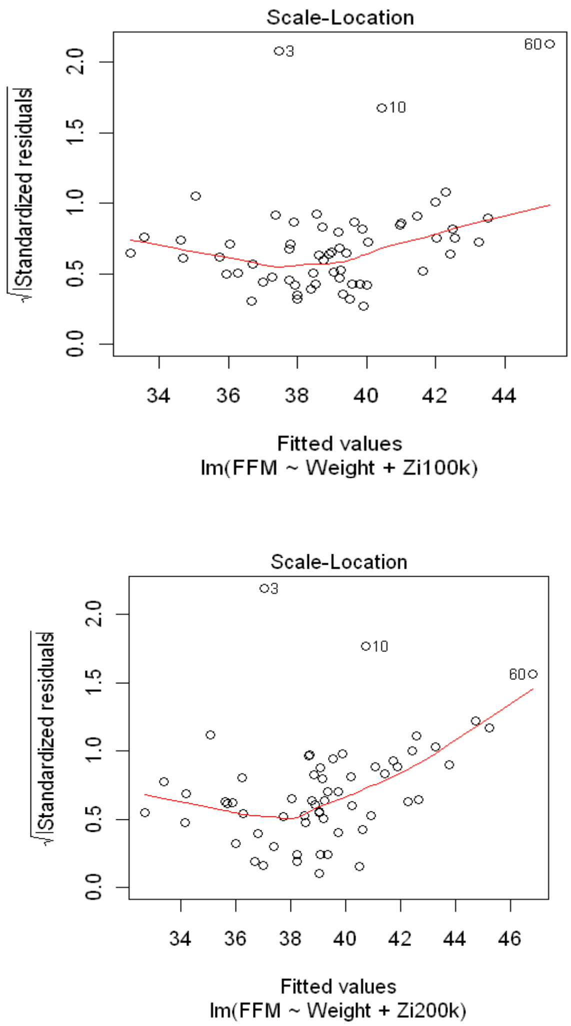
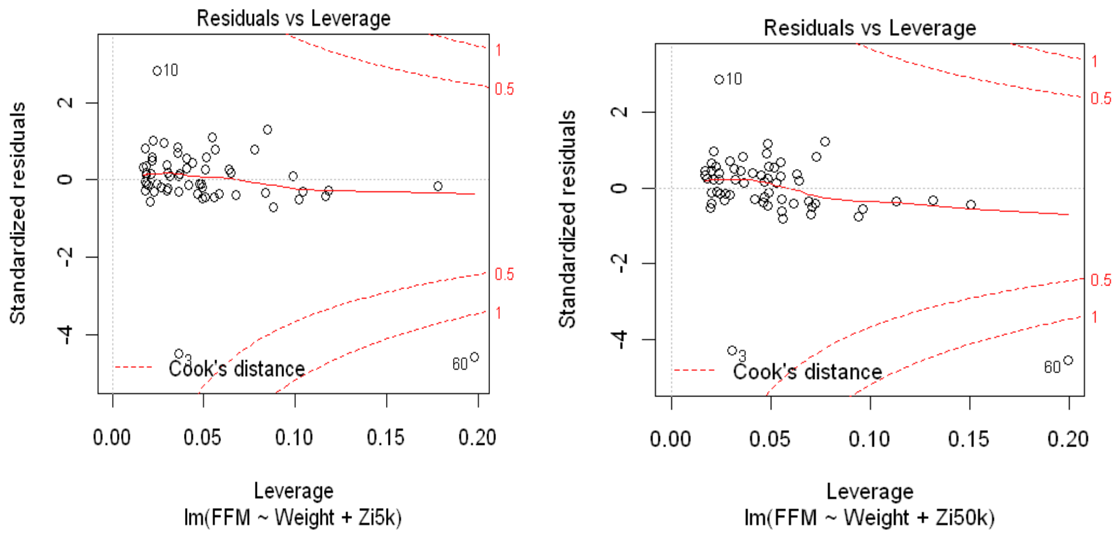


Fig10: Scale location plot between the square root of standardized residuals versus fitted values of Indian females showing the relationship between Fat Free Mass(FFM)in (Kg) , Impedance Index (Height^2/Impedance of body at 5KHz,50KHz.,100KHz.,200KHz.frequencies)in (cm^2/Ω) and Weight of body in Kg.



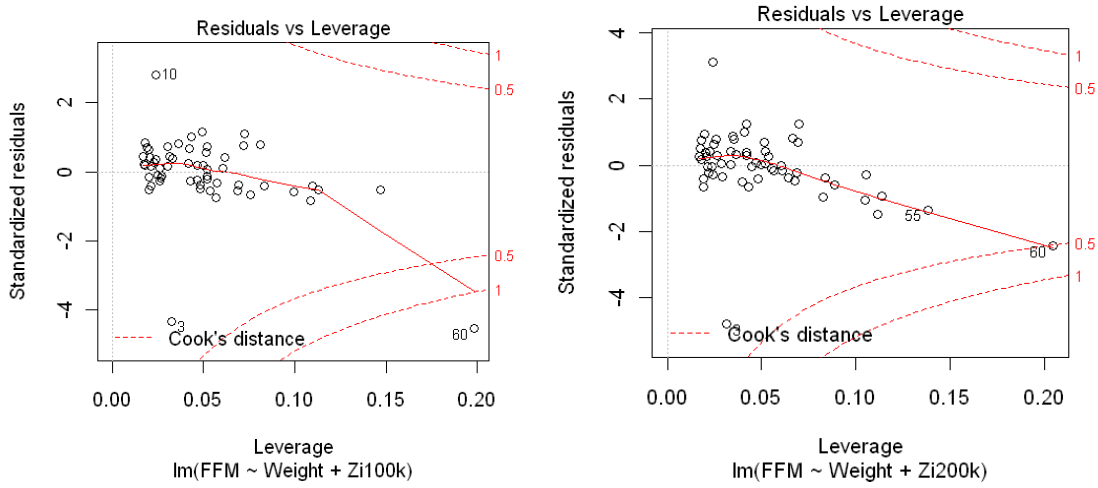


Fig11: Residual versus leverage plot and standardised residuals verses cook's distance plot of Indian females showing the relationship between Fat Free Mass(FFM)in (Kg) , Impedance Index (Height^2/Impedance of body at 5KHz,50KHz,100KHz,200KHz.frequencies)in (cm^2/Ω) and Weight of body in Kg.

Comparision of measured and predicted results: The Table below shows the comparative of measured and predicted values of TBW and FFM at frequencies of 5KHz,50KHz,100KHz and 200 KHz.

TABLE 4:

S.No.	TBW predicted at 5KHz.	TBW predicted at 50KHz	TBW predicted at 100 KHz	TBW predicted at 200 KHz	TBW measured	FFM predicted at 5KHz	FFM predicted at 50 KHz	FFM predicted at 100 KHz	FFM predicted at 200 KHz	FFM measrured
1.	23.911	24.089	24.069	24.008	24.35	37.958	37.98	37.986	37.36	37.61
2.	25.38	25.82	25.736	26.132	26.22	38.688	39.365	39.247	39.72	38.38
3.	24.028	23.768	23.927	23.86	11.82	37.79	37.208	37.455	37.04	24.02
4.	26.687	27.373	27.209	27.557	27.79	40.308	41.24	41.005	41.418	43.27
5.	25.294	24.853	24.649	24.95	25.28	40.176	38.769	38.448	38.487	39.23
6.	30.497	30.028	30.025	29.917	30.19	43.57	43.41	43.503	43.76	45.91
7.	25.866	25.816	26.031	25.93	35.81	38.913	38.83	39.21	39.202	39.9
8.	22.505	22.830	22.928	22.58	23.27	36.95	36.98	37.37	35.89	34.87
9.	25.328	25.116	25.342	25.24	25.39	37.722	37.63	37.99	38.211	38.31
10.	27.553	27.5	27.529	27.412	27.38	40.539	40.39	40.45	40.744	49.24
11.	23.143	23.079	22.903	22.838	23.06	36.256	36.25	35.92	35.687	36.7
12.	26.212	26.039	26.051	25.96	26.04	40.101	39.427	39.52	39.355	39.2
13.	21.516	21.349	21.401	21.357	21.64	40.432	34.608	34.677	34.142	33.54
14.	23.275	23.558	23.511	23.452	24.03	36.969	37.34	37.279	26.227	36.59
15.	26.405	26.033	26.086	25.98	25.73	39.263	38.675	38.745	39.035	39.86
16.	25.878	26.321	26.102	26.016	26.24	39.784	40.225	39.89	39.55	41.94
17.	27.154	27.053	27.443	27.32	27.16	39.235	39.36	40.02	40.496	40.56
18.	21.329	21.394	21.518	21.47	21.6	33.925	34.42	34.603	34.011	32.93
19.	25.87	25.338	25.534	25.426	25.22	38.078	37.484	36.552	38.238	38.4
20.	28.286	28.268	28.178	28.083	28.66	42.163	41.713	41.63	41.71	44.04
21.	26.333	26.07	26.179	26.07	25.85	38.68	38.339	38.629	39.045	39.88
22.	24.529	24.244	24.428	24.33	24.21	36.373	36.4	36.66	37.017	36.95
23.	26.304	25.547	25.443	25.35	25.93	38.36	38.89	38.75	39.15	40.89
24.	27.621	27.688	27.660	27.55	27.51	41.477	40.98	40.96	41.055	43.19
25.	29.346	29.42	29.369	29.227	29.13	41.98	42.104	42.018	42.65	43.77
26.	24.709	24.57	24.67	24.59	24.35	38.04	37.768	37.928	37.74	38.47
27.	27.221	27.089	27.167	27.05	27.25	39.804	39.73	39.812	40.22	39.25
28.	23.07	22.9	22.947	22.87	23.13	35.673	35.68	35.73	35.627	34.56
29.	25.798	25.73	25.625	25.538	26.08	39.604	39.218	39.05	38.87	39.88
30.	27.92	28.51	28.49	28.381	28.81	41.777	42.39	42.43	42.25	41.2
31.	27.596	27.585	27.696	27.565	27.62	39.370	39.75	39.907	40.613	40.13
32.	25.882	26.003	25.866	25.774	26.24	39.371	39.415	39.197	39.09	41.18
33.	26.622	26.43	26.563	26.458	26.62	39.74	39.36	39.586	39.72	40.16
34.	29.049	29.09	29.045	28.917	28.9	42.589	42.33	42.285	42.55	45.89
35.	28.522	28.583	28.574	28.93	28.3	41.42	41.46	41.455	41.877	44
36.	29.314	29.247	29.029	28.89	29.01	42.75	42.336	41.98	42.41	45.1

37.	25.53	25.469	25.667	25.57	25.35	38.17	41.238	38.566	38.679	41.25
38.	26.033	25.131	25.215	25.116	25s	39.28	37.656	37.76	38.03	39.17
39.	26.329	26.133	26.27	26.155	26.32	38.25	38.319	38.51	39.05	39.08
40.	23.684	23.403	23.573	23.496	23.51	36.19	36.016	36.27	36.28	37.06
41.	20.236	20.04	20.217	20.18	20.75	32.77	32.91	33.149	32.68	31.91
42.	25.613	25.5	25.563	25.465	25.85	38.35	38.29	38.38	38.53	37.91
43.	25.589	25.51	25.361	25.29	25.49	40.41	39.626	39.42	38.856	40.7
44.	26.36	26.22	26.201	26.1	25.99	39.59	39.27	39.23	39.325	40.67
45.	20.867	20.696	20.759	20.825	21.06	33.325	33.488	33.55	33.38	31.81
46.	25.388	25.547	25.557	25.47	25.74	38.48	38.898	38.93	38.77	37.66
47.	26.358	25.807	26.175	26.05	25.7	37.47	37.232	37.78	38.67	36.27
48.	22.823	23.048	22.86	22.8	23.07	36.814	36.99	36.69	35.98	35.71
49.	22.984	23.355	23.196	23.47	23.88	36.748	37.25	37.003	36.822	36.4
50.	23.032	22.35	22.559	22.49	25.96	34.574	34.75	35.042	35.07	38.4
51.	23.526	23.347	23.448	23.47	23.5	35.84	35.919	36.05	36.25	34.51
52.	26.216	26.208	26.227	26.12	26.21	38.84	38.975	38.99	39.24	40.34
53.	29.108	29.63	29.521	29.85	29.6	42.33	42.73	42.56	43.67	40.84
54.	24.825	25.75	25.644	26.08	26.25	38.29	39.78	39.644	39.88	37.34
55.	31.159	31.33	31.497	31.75	31.27	42.2	43.002	43.25	45.22	41.73
56.	26.99	26.975	26.98	26.87	25.96	40.138	40.024	40.04	40.199	38.4
57.	27.832	28.754	28.68	29.155	29.11	41.159	42.546	42.49	43.25	40.47
58.	27.568	27.472	25.91	27.466	27.61	40.99	40.614	37.88	40.94	40.18
59.	25.639	25.893	28.156	25.69	26.02	39.25	39.499	39.326	39.09	38.93
60.	33.504	33.371	33.45	33.26	32.48	45.178	45.178	45.316	46.81	40.8

Results and Discussion: The physical characteristics of samples are shown in Table 1 and Table 2. The prediction equations developed for Total Body Water at 5 KHz, 50 KHz, 100 KHz and 200 KHz. are as shown below:

TBW_{BIA}= (0.24689)×ZI_{5k} + (0.25593)×Body weight + 5.58336 ………………(1)

TBW_{BIA}= (0.0.22363)×ZI_{50k} + (0.29178)×Body weight + 4.89741 ………………(2)

TBW_{BIA}= (0.23751)×ZI_{100k} + (0.24204)×Body weight + 5.31032 ………………(3)

TBW_{BIA}= (0.0.22363)×ZI_{200k} + (0.29178)×Body weight + 4.89741 ………………(4)

Where TBW_{BIA} is Total body water in litres, ZI_{5k} $ZI_{50k,}$ $ZI_{100k,}$ ZI_{200k} is Impedance indexes of the body at 5KHz,50 KHz,100KHz,200 KHz respectively in (cm^2/Ω). Body weight is the weight of the body in Kg.
The prediction equations developed for Fat Free Mass at 5 KHz, 50 KHz, 100 KHz and 200 KHz. are as shown below:

FFM_{BIA}= (0.12496)×ZI_{5k} + (0.56707)×Body weight + 15.91914 ………………(5)

FFM_{BIA}= (0.11924)×ZI_{50k} + (0.50014)×Body weight + 16.70689 ………………(6)

FFM_{BIA}= (0.13920)×ZI_{100k} + (0.42686)×Body weight + 17.20722 ………………(7)

FFM_{BIA}= (0.21844)×ZI_{200k} + (0.34863)×Body weight + 15.78796 ………………(8)

Where FFM_{BIA} is Total body water in Kg, ZI_{5k} $ZI_{50k,}$ $ZI_{100k,}$ ZI_{200k} is Impedance indexes of the body at 5KHz, 50 KHz, 100KHz, 200 KHz respectively in (cm^2/Ω). Body weight is the weight of the body in Kg. The other statistical analysis such as Standard Error of Estimate (S.E.E.) for Intercept, Impedance index at 5KHz, 50KHz, 100KHz and 200 KHz, Residual Standard Error (R.S.E.), Multiple R squared, mean standard deviation of predictor variable i.e. Impedance index and weight and dependent variable i.e. TBW and FFM at 5KHz, 50KHz, 100KHz and 200 KHz are given in Table 3.

A comparative study of TBW and FFM at frequencies of 5 KHz, 50 KHz, 100 KHz and 200 KHz is shown in Table 4. From the results obtained it is seen that predicted values are very close to measured values. However, predicted values of TBW and FFM at 50 KHz, 100 KHz and 200 KHz are much closer to measured values then the predicted values at 5 KHz. This is due to the fact that at low frequencies, the current cannot bridge the cellular membrane and will pass predominantly through the extracellular space. At higher frequencies penetration of the cell membrane occurs and the current is conducted by both the extra-cellular water (ECW) and intra-cellular water (ICW).

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