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Interpreting Health Status Of Indian Population Using Phase Angle As Health Parameter.

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Abstract: Bio Electrical Impedance Analyser is a simple Non-Invasive tool that is used for the Human body composition Analysis. It has been found that the basic principle of Human Body composition Analysis is the measurement of fat vs lean muscle tissue. And it is well known fact that biological tissues the path of least resistance. While Analysing the body composition through Bio Electrical Impedance Analyser body resistance and body reactance are taken into account. Phase Angle is directly calculated from resistance and reactance and Phase Angle is an important indicator of cellular health and integrity. This paper aims at discussing the significance of Phase Angle in Analysis of Human Body Composition and developing and validating prediction equation of Phase Angle at different frequencies.

Keywords: Phase Angle, Body Mass Index, %Fat Mass, sex,age, Fat Free Mass, Total Body Water, Impedance Index(Ht.^{2}/Z).

I. Introduction

Phase Angle is an important parameter in analysis of the body composition of subjects. It gives the linear relationship of reactance and resistance in series and parallel circuit and is defined as Phase Angle = arc tan (reactance/resistance).

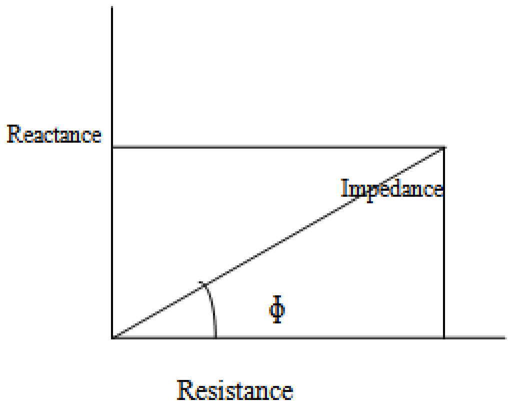


Fig1:Body Phase Angle

Phase angle is an indicator of cell health and integrity. For low phase angle would imply that the low reactance of cell and henceforth, cell death or cell breakdown in the selective permeability of the cell membrane. High phase angle would imply higher reactance and large quantities of intact cell membrane and body cell mass. Frequency plays an important role in determining how the cell tissues will react.At low frequency (in the range 1 to 5 kHz (Kilo Hertz))the current have difficulty overcoming the cell membranes, and are therefore will only pass through the extra-cellular mass, which means they practically hold no reactance component. That's why, multi frequencies are used to calculate ECW (Extra Cellular Water). As the frequency increases, so does the phase angle and with it the capacitive resistance (reactance). The maximum frequency is reached at about 50 kHz. Higher frequencies will cause both, the resistance and the reactance to decrease again. Cole defined this relationship between frequencies and resistances in 1968, and the graphical representation of the correlation between resistance and reactance at different frequencies is called a Coleplot.

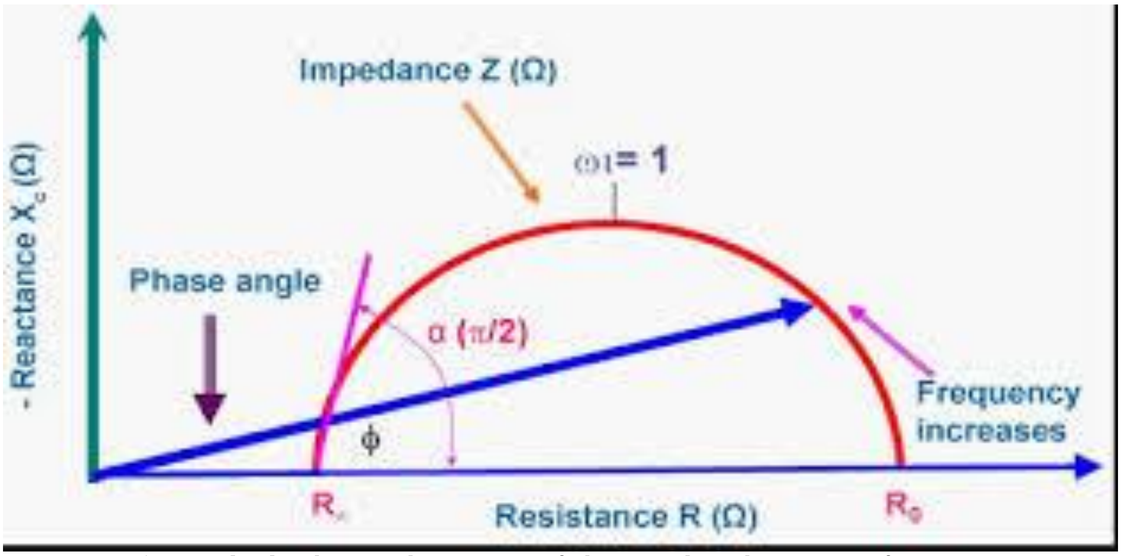


Fig 2: Cole plot showing the variation of Phase Angle with increasing frequency

At high frequency the current is conducted by both Extra Cellular Water and Intra Cellular Water and penetration of Cell Membrane occurs. Therefore, generally phase Angle is taken as 50 KHz while developing the prediction so that current is conducted by both Extra Cellular Water and Intra Cellular Water.

The use of multi-frequency analysis provides an improved differentiation with regard to cell loss or water displacement, by assessing variations in mass of the extra-cellular mass ECM and the body cell mass BCM. This process is especially beneficial in patients with a changed grade of hydration in the lean body mass, and patients with serious illness such as kidney or heart failure, or patients with edema and diseases that require the crucial monitoring of water balance (dialysis, intravenous nutrition).

The relationship between Basal metabolic rate and body weight and body composition have been evaluated using Sex age weight and Impedance Index as the parameter for developing the prediction equation at multiple frequency. Research have shown that phase angle is an Important parameter for developing Basal metabolic rate. It should be noted that Basal Metabolic rate and Resting Metabolic Rate are used interchangeably, except that readings for Basal Metabolic Rate are more accurate. This paper aims at developing the multiple Regression equation for Basal Metabolic rate and validating the results with clinical data. Generally we used indirect calorimetry for measuring REE or RMR or BMR. However, for this paper we have used Maltron-II BIA Analyser.

Energy intake assessment is necessary for nutritionist, as it gives them the hazy idea about the eating habits and general disorders about in the body of individual. An estimated 25 million Indians have diabetes, and this is forecast to grow to 57 million by 2025.The rural section of the country is facing the different challenge of under nutrition. It is found mostly in rural areas and is concentrated in a relatively small number of districts and villages; with 10 percent of villages and districts accounting for of all underweight children. So; all in all, we can say that India is facing the dual challenge of obesity and undernourishment. Individuals who are overweight or obese are at the risk of developing cardiovascular, pulmonary, metabolic disease, osteoarthritis and certain types of cancer. On the other hand underweight individuals are malnourished and have a high risk of fluid-electrolyte imbalances, renal and reproductive disorders. Body composition analysis (BCA) therefore; was therefore, necessary to yield data about normal growth, maturity, and longer life.

Besides this, numerous studies indicate that malnutrition is another serious health concern that Indian subject 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 body composition of Indian subjects database to develop and predict two sets of equation ;REE using independent sets of variable sex, weight and Stature of body at the frequencies of 5KHz, 50KHz, 100KHz, 200KHz.The other set of REE is developed using sex, age, Impedance index, weight and Phase Angle. We have included parameter of Phase Angle in predicting REE at different frequency because it provide physician with more accurate data regarding different Extracellular to Intracellular water. T he graphic presentation of the results is another benefit. It provides a summary and overview and helps visualize the data.

The obtained equations are of the form:
REE(f1,f2)=a0Sex+

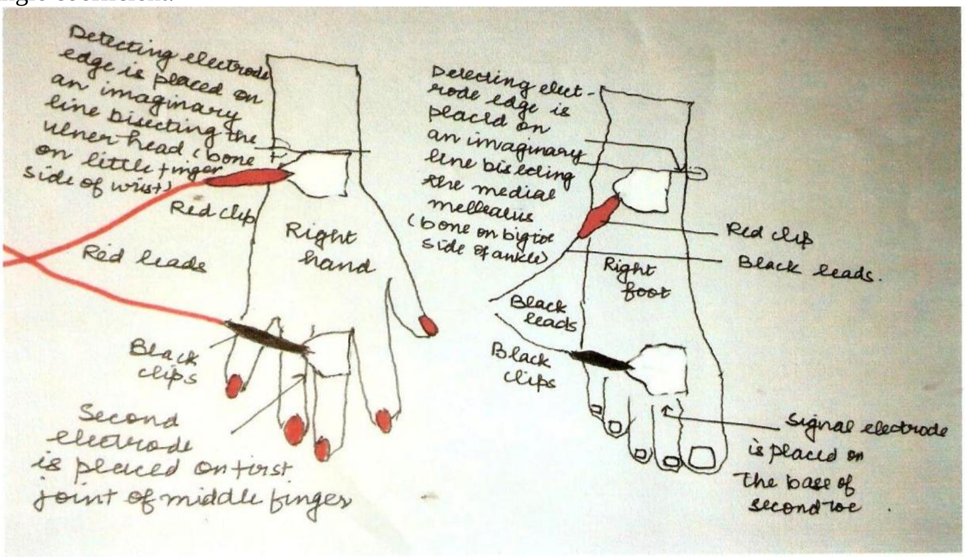
Subjects and Procedure:

Human Body Composition data of 54 subjects (49males and 5 females) within the age group of 23 yrs to 50 yrs were studied through Maltron-II Body Composition Impedance Analyzer method; where excitation current of 800µA at different frequencies of 5 KHz, 50 KHz, 100 KHz and 200 KHz were applied to the source or drive distal electrodes on the hand and foot; and the voltage drop due to impedance is detected by sensor electrodes on the wrist and ankle. The figure and block diagram representation of the control process is shown below:

a1 Wt.+a2 ZI(f1,f2)+C1 ....(1)

REE=b0Sex+b1Wt.+b2 ZI(f2). +b3 (PA)+C2 ………(2)

Where REE(f1,f2,f3,f4) is the Resting Energy Expenditure of individual at the frequency of 5KHz, 50 KHz .REE is Resting Energy Expenditure at constant frequency .C1 and C2 are intercepts of equation (1) and (2) respectively and a0, b0 are coefficients multiplied by sex variable of equation(1) and(2) respectively and a1, b1 are coefficients multiplied by Wt. variable of equation(1) and(2) respectively.a2,b2 is the coefficient multiplied by Impedance Index at frequency of 5KHz, 50 KHz, 100KHz and 200KHz.,b3 is the coefficient multiplied by phase angle coefficient.



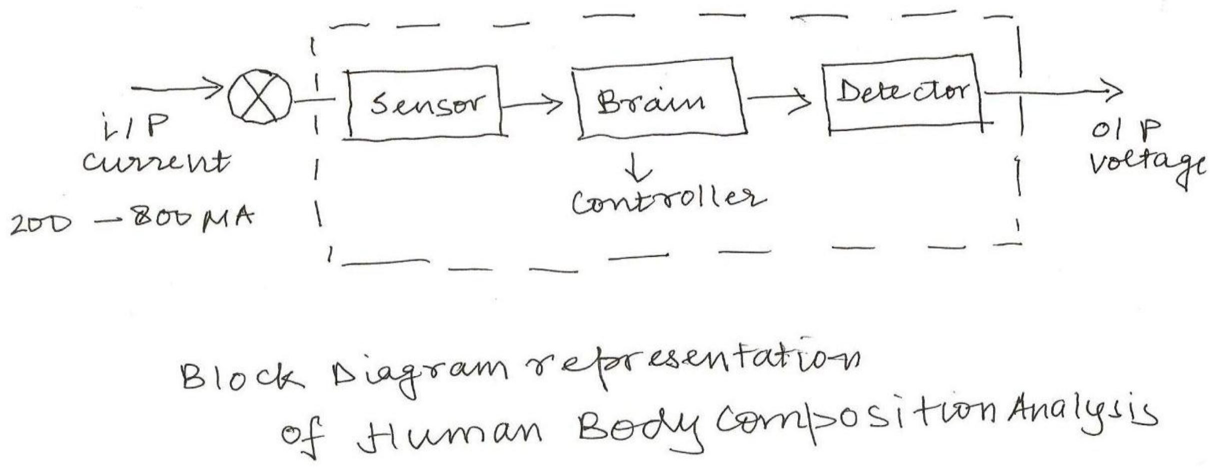


Fig3: Procedure for measuring experimental data of using Maltron-II Bio Electrical Impedance Analyzer.

These clinical data were then utilized to calculate the Impedance Index i.e. (height^2/impedance) at different frequencies of 5 KHz, 50 KHz, 100 KHz and 200 KHz. The calculated impedance index of each individual at different frequency is formulated in the form of Table (1). Finally multiple regression analysis of these data was carried out to develop and design a linear model with the help of R software (version 2.14.1).Two sets of REE were developed. REE using independent sets of variable sex, weight and Impedance Index of body at the frequencies of 5KHz, 50KHz, 100KHz, 200KHz.The other set of REE is developed using sex, age, Impedance index, weight and Phase Angle at the frequencies of 5KHz, 50KHz, 100KHz, 200KHz. For this, an algorithm was developed and statistical analysis of the data was done; the flow chart showing the actual process carried out to generate the linear model and Descriptive statistics is shown below in fig. (4) and Table (1) respectively.

Variables	**Mean ± S.D.**
Weight	60.35185 ± 12.1156493
Sex	49males and 5 females
Age	20.74 ± 4.7324
REE	1488.82 ± 192.1440632
Zi at 5 KHz	38.006039±6.9973077
Zi at 50 KHz	43.7616 ± 8.22416
PA at 50 KHz	7.8357 ± 0.719608

Table1: Descriptive statistics of Indian Subjects (n=54)

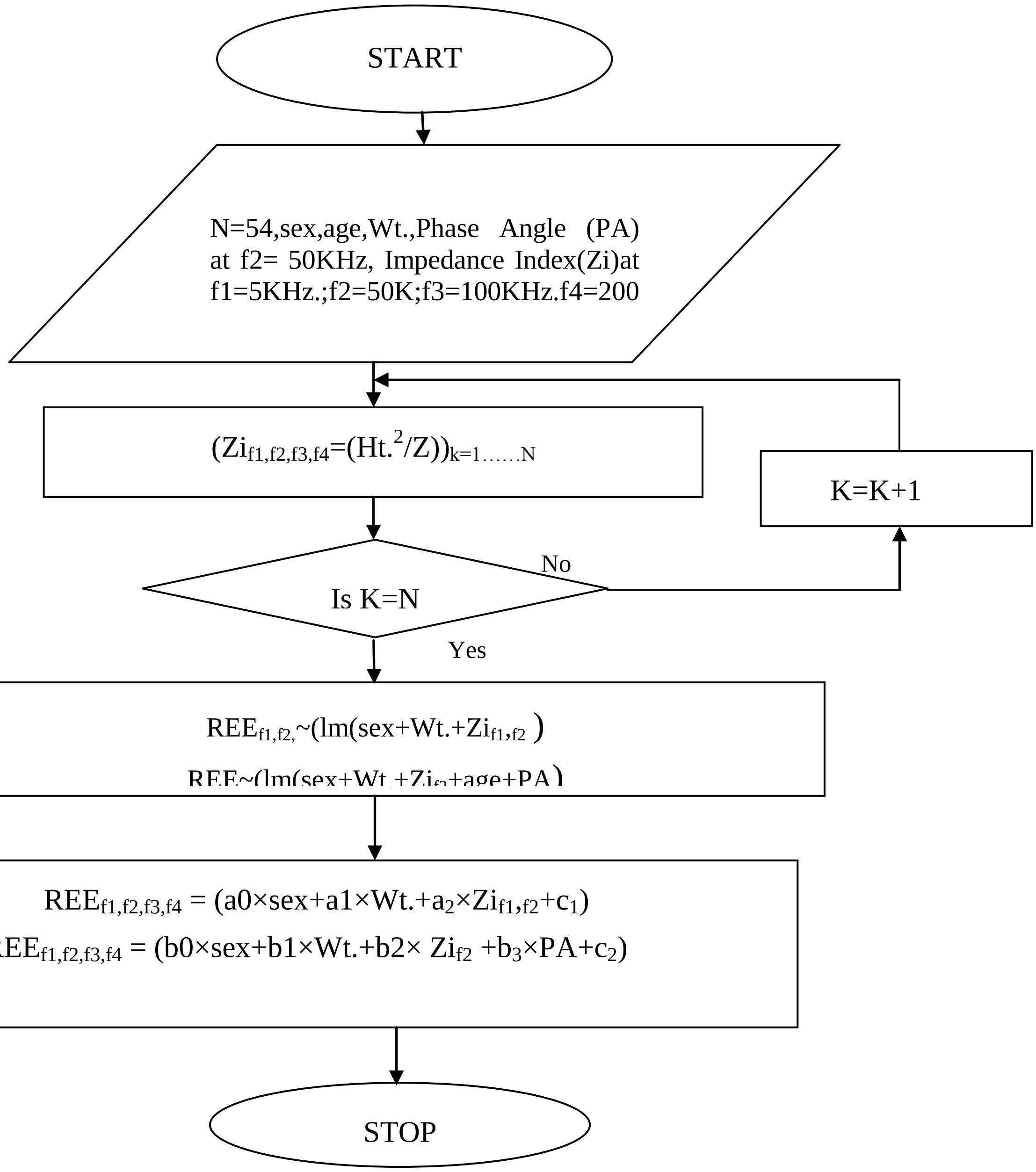


Fig4: Flowchart showing the general process to develop 2 sets of linear model of REE at the frequencies of 5 KHz and 50 KHz .

Prediction Equation developed:

It provides a summary and overview and helps visualize the data.

The obtained equations are of the form:

REE(f1,f2)=a0Sex+a1 Wt.+a2 ZI(f1,f2)+C1 ....(1)

REE=b0Sex+b1Wt.+b2 ZI(f2). +b3 (PA)+C2 ………(2)

Where REE(f1,f2,f3,f4) is the Resting Energy Expenditure of individual at the frequency of 5KHz, 50 KHz .REE is Resting Energy Expenditure at constant frequency .C1 and C2 are intercepts of equation (1) and (2) respectively and a0, b0 are coefficients multiplied by sex variable of equation(1) and(2) respectively and a1, b1 are coefficients multiplied by Wt. variable of equation(1) and(2) respectively.a2,b2 is the coefficient multiplied by Impedance Index at frequency of 5KHz, 50 KHz, 100KHz and 200KHz.,b3 is the coefficient multiplied by phase angle coefficient.

The table below shows the descriptive statistic and Prediction equation developed:

Table 2: Descriptive statistics of Indian subjects (n=54) together with REE equations developed

S.No.	Prediction Equation developed	Frequency used	Standard Error	Residual Error Multiple R^2	Adjusted R^2
1.	REE5k=157.516×sex+1.917×Wt. +19.816×Zi_{5kHz} + 597.143	5KHz	Intercept=44.553 Sex= 26.924 Wt.=1.029 Zi5=1.867	56.89 on 50 df 0.9164 54.84 on 50 df 0.9223	0.9114
2.	REE50k=141.922×sex+2.215×Wt.+16.866×Zi_{50kHz} + 608.065	50KHz	Intercept=42.501 Sex= 26.365 Wt.=0.963 Zi50=1.508	54.24on 49 df 0.9255	0.9176
3.	REE=141.8153×sex+2.4003×Wt +16.800×Zi_{50kHz} + --15.221PA+719.1448	50KHz	Intercept=87.4385 Sex= 26.0804 Wt.=0.9611 Zi50=1.4924 PA50=10.5065		0.9194

II. RESULTS AND DISCUSSION

The study was able to develop REE prediction equation for Indian subjects. Data used in commercial software provided 2 BIA equations at 5 KHz, 50 KHz as shown below:

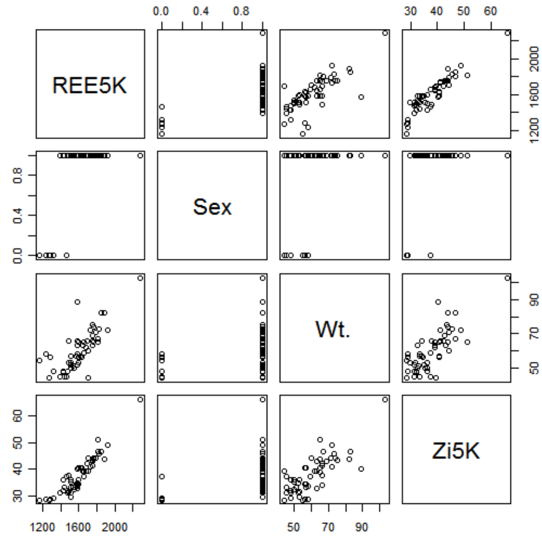
$$REE(5KHz) = 157.516\times Sex+1.917\times Wt.+19.816\times Zi_{5KHz}+597.143 \quad \ldots\ldots\ldots(3)$$

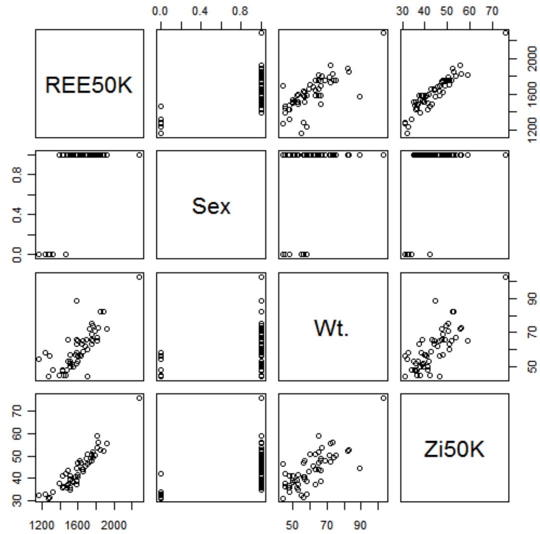
$$REE(50KHz) = 141.922\times Sex+2.215\times Wt.+16.866\times Zi_{50\,kHz} + 608.065 \quad \ldots\ldots..(4)$$

In a similar pattern the prediction equation for REE was developed at 50KHz frequency taking Phase angle as independent variable. We have not taken the reading at lower and high frequency because as explained in cole plot phase angle is low similarly the reactance component start decreasing at high frequency too and current cannot bridge the cell membrane and will pass through Extra Cellular Space only.Therefore, reading is taken at Phase angle 50 KHz and Zi 50KHz :

$$REE = 141.8153\times Sex+2.4003\times Wt.+16.800\times Zi_{50\,kHz} -15.221PA+719.1448 \quad ....(5)$$

where REE(5 KHz), REE(50 KHz),and REE is Resting Energy Expenditure of body KCal at5 KHz,50 KHz, $ZI_{5\,kHz,}$ $Zi_{50\,kHz}$ is Impedance index of body at 5KHz and 50 KHz, frequency respectively in (cm^2/Ω). Value of sex of the subject is taken as 1 for female and 0 for male subject.Wt.is the weight of the body in Kg. Besides, development of BIA equations; statistical analysis of the data of data was also done the results of which were tabulated in table (3).In addition to this graphical analysis of the data is shown in Fig (5), Fig (6), Fig (7), Fig (8), Fig (9), Fig (10), Fig (8),and Fig (11). These figures showed different graphical plots such as scatter matrix plot for Resting Energy Expenditure (REE) at different frequencies, normal distribution of standardized residuals, Scale location plot, Residual verses leverage plot and standardized residual verses cook's distance plot. These plots for linear model objects give the diagnostic information about the linear model. Besides this, a comparative study of measured and predicted Resting Energy Expenditure(REE) at the frequencies of 5KHz, 50KHzis tabulated in Table (4) and from the results it is observed that the predicted value of REE at these frequencies are very much closer to the measured value.





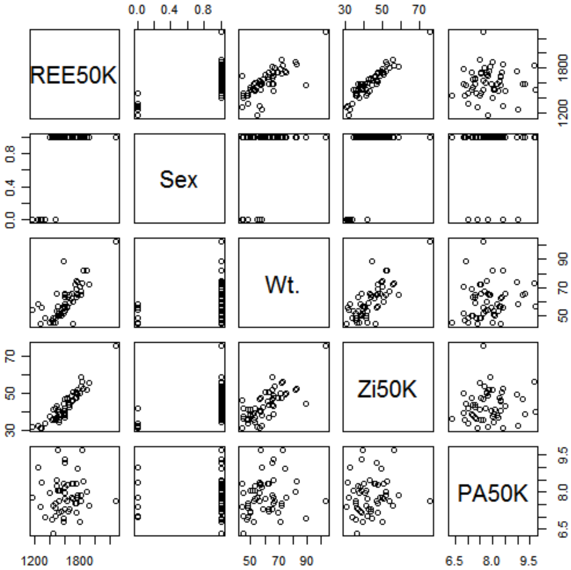
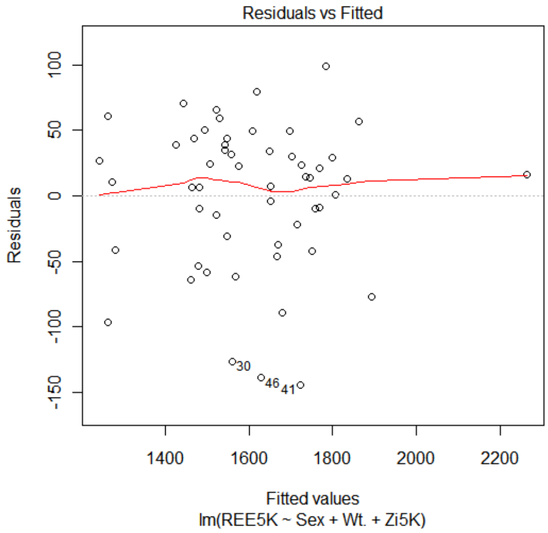
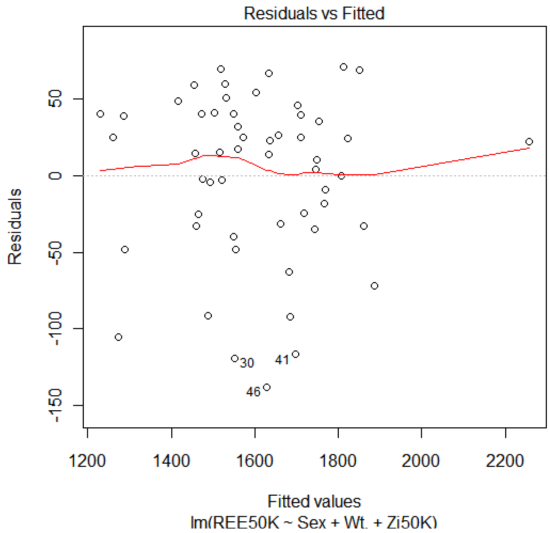


Fig.5: Scatter Plot Matrix distribution of body composition of Indian subjects; showing the relationship between Resting Energy Expenditure (REE) in KCal, Impedance Index (Stature) (Height^2/Impedance) of body at frequencies of 5KHz,50KHz in (cm^2/Ω) and Weight of body in Kg, sex of the subject and Phase Angle at frequency of 50 KHz.





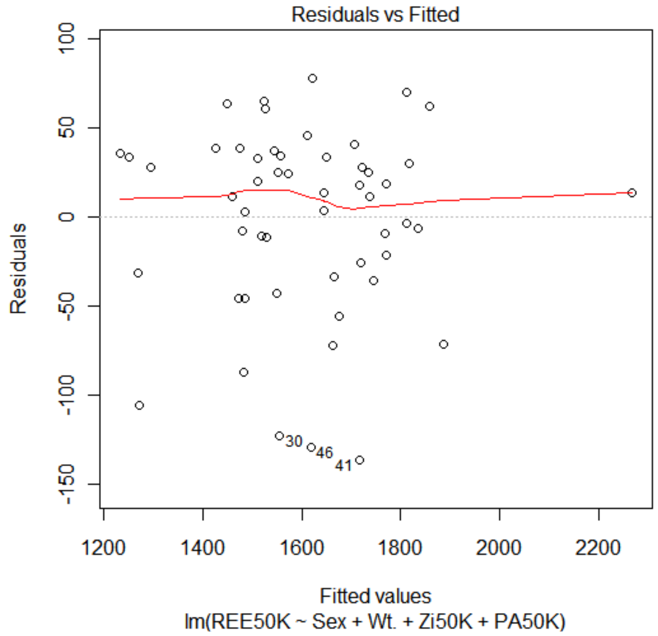
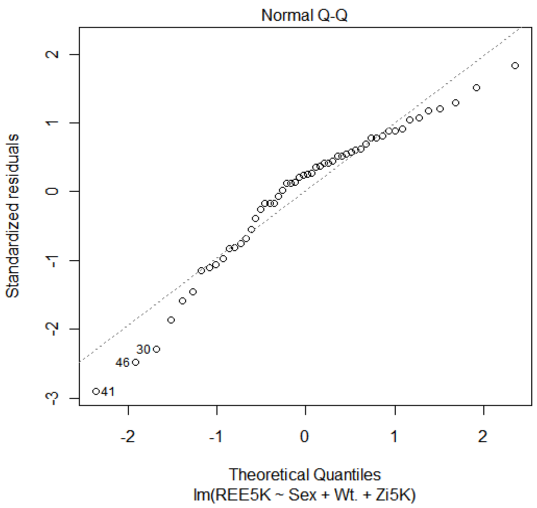
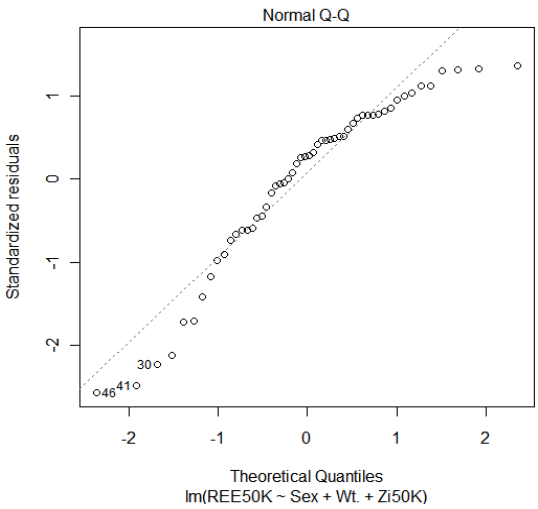


Fig.5: Residual Vs Fitted plot of body composition of Indian subjects; showing the relationship between Resting Energy Expenditure (REE) in KCal, Impedance Index (Stature) (Height^2/Impedance) of body at frequencies of 5KHz,50KHz in (cm^2/Ω) and Weight of body in Kg, sex of the subject and Phase Angle at frequency of 50 KHz.





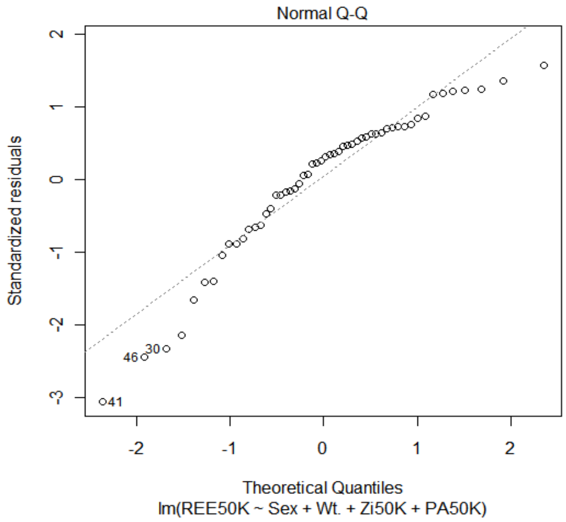
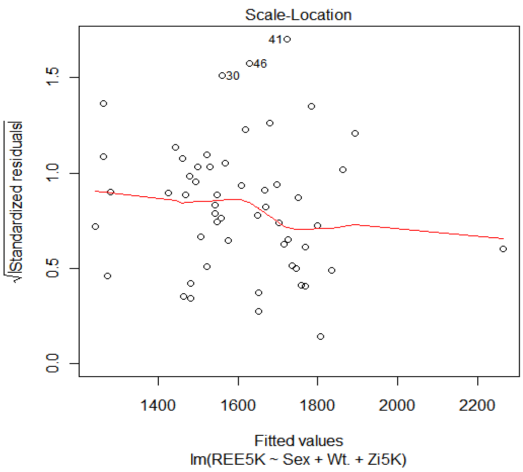


Fig.6: Normal Vs Standardised residual plot of body composition of Indian subjects; showing the relationship between Resting Energy Expenditure (REE) in KCal, Impedance Index (Stature) ($Height^2$/Impedance) of body at frequencies of 5KHz,50KHz in (cm^2/Ω) and Weight of body in Kg, sex of the subject and Phase Angle at frequency of 50 KHz.



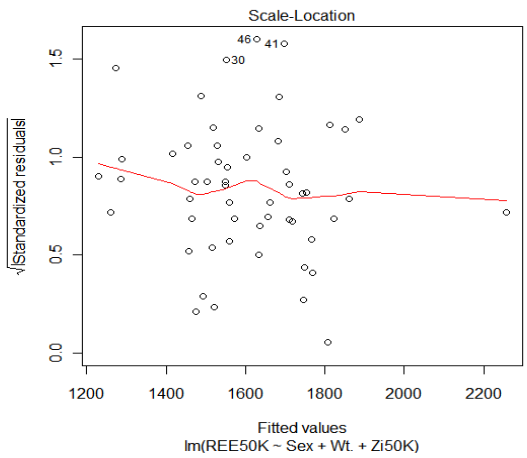
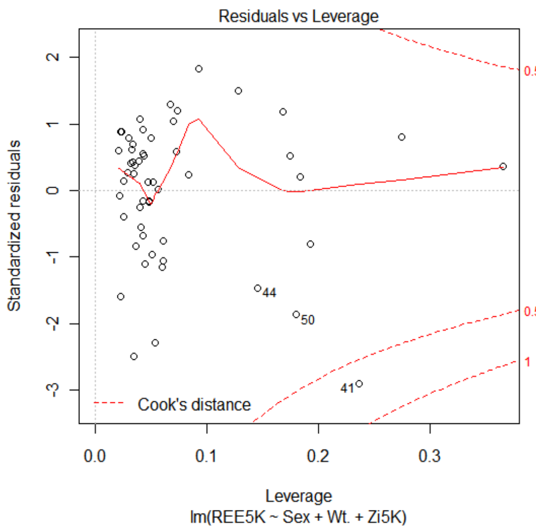
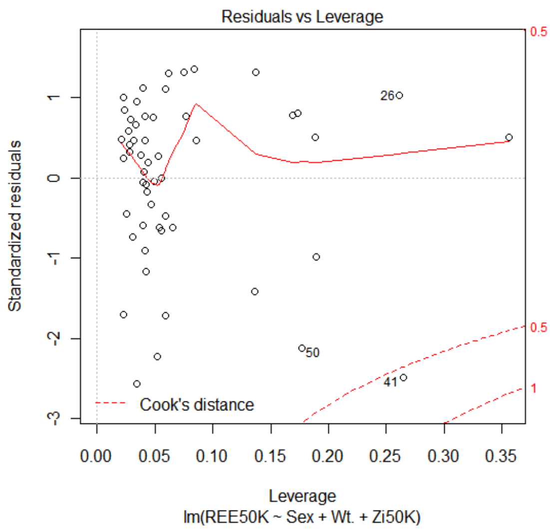


Fig.7: Scale location plot of body composition of Indian subjects; showing the relationship between Resting Energy Expenditure (REE) in KCal, Impedance Index (Stature) (Height^2/Impedance) of body at frequencies of 5KHz,50KHz in (cm^2/Ω) and Weight of body in Kg, sex of the subject and Phase Angle at frequency of 50 KHz.





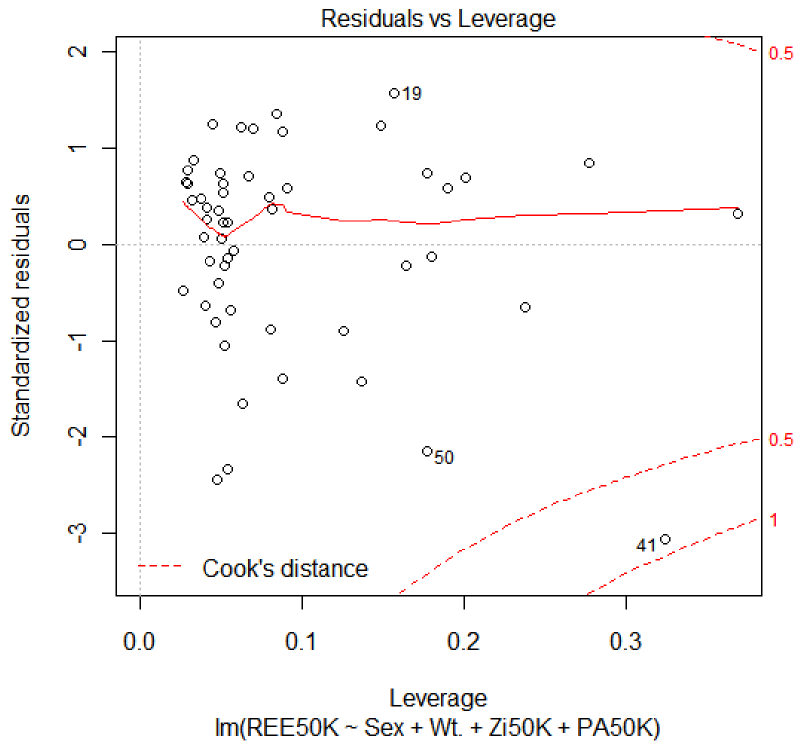


Fig.8: Residual Vs Leverage plot of body composition of Indian subjects; showing the relationship between Resting Energy Expenditure (REE) in KCal, Impedance Index (Stature) (Height^2/Impedance) of body at frequencies of 5KHz,50KHz in (cm^2/Ω) and Weight of body in Kg, sex of the subject and Phase Angle at frequency of 50 KHz.

Table 3: Comparative study of measured and predicted value of REE at different frequencies of participants for N= 10 out of 54 data

S.No.	REE predicted at 5KHz.	REE predicted at 50KHz	REE measured with PA	REE measured from BIA analyser
1.	1680.534	1683.391	1663.686	1591
2.	1627.974	1627.192	1618.155	1489
3.	1523.444	1548.536	1519.797	1509
4.	1522.183	1518.145	1527.219	1588
5.	1557.311	1548.689	1527.783	1589
6.	1264.354	1273.414	1273.737	1168
7.	1275.216	1260.736	1252.268	1286
8.	1281.328	1288.475	1271.153	1240
9.	1263.676	1285.805	1255.9	1325
10.	1244.305	1230.446	1234.989	1271

III. CONCLUSION

The body composition parameters of the samples (54subjects) measured through instrument Maltron-II Body Composition Impedance Analyzer at frequencies of 5 KHz,50KHz were utilized to obtain BIA equations. To do the same; multiple regression analysis was carried out on clinical data through R (2.14.1) software. The instrument has many advantages over other methods and is safe, rapid, portable, easy to perform and require minimum operator training. The BIA prediction equation for Total Body water and Fat Free mass was developed at different frequencies. These prediction equation developed in the present paper is the first BIA prediction equation REEfor Indian subjects. The predicted REE of each individual are very close to the one measured through instrument. However, it is observed that at higher frequencies the results are much closer to the measured value. 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, whereas 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). Based on these BIA equations, a general idea about the dietary habits of Indian subjects can be predicted which can be utilized for variety of clinical and research applications; as information about lean tissue mass, fat tissue mass, and fractional contribution of fat makes them excellent for monitoring pharmaceutical therapy, nutritional or exercise intervention, sports training &/or other body composition altering programs. Besides this, the information regarding the dietary habits of Indian subjects will give the pharmaceutical companies a chance to explore the change in body composition of Indian subjects before and after drug therapy. It will also provide coaches and researchers, the initial information about health criteria of given population.

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