Estimation of Body Fat using Bioelectric Impedance Analysis

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----------**ABSTRACT**----------

Fat is one of the major problem in youngsters, adults and in old age people. It has always been easy to record one's weight loss. However, it is more tedious to measure one's body fat percentage. Certain methods include skin capillary and hydrostatic under water weighing which are not simple. One can also roughly estimate their body fat percentage by looking in the mirror. However, bio-electrical impedance analysis provides a quick and easy method to estimate one's fat content. In this proposed work we determine the opposition to the electric current through the body tissues to estimate the body fat percentage.

Keywords -**Obesity, BIA, Body fat percentage, electrodes**

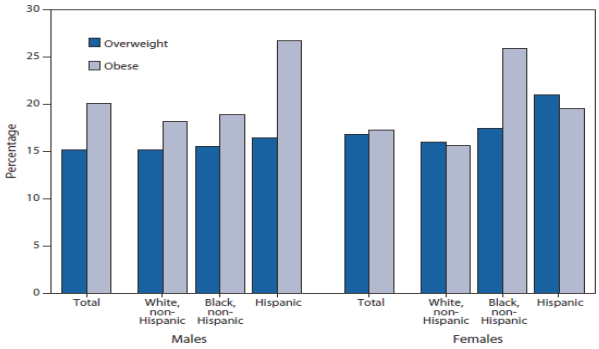
I. INTRODUCTION

Bioelectrical Impedance is measured when a very small electrical signal carried by water and fluids is passed through the body. Impedance is greatest in fat tissue, which contains only 10-20% water, while fat-free mass, which contains 70-75% water, allows the signal to pass much more easily. By using the impedance measurements along with a person's height and weight, and body type (gender, age, fitness level), it is possible to calculate the percentage of body fat, fat-free mass, hydration level, and other body composition values.

Using BIA to estimate person's body fat assumes that the body is within normal hydration ranges. When a person is dehydrated, the amount of fat tissue can be overestimated. Factors that can affect hydration include not drinking enough fluids, drinking too much caffeine or alcohol, exercising or eating just before measuring, certain prescription drugs or diuretics, illness, or a woman's menstrual cycle B.I.A. is the measurement of electrical resistance in an organic body. A constant field of alternating electric current is created in the patient's body, via electrodes on the skin, and the total resistance = impedance (Z), is measured in Ω (Ohms).

A. Prevalence of healthy weight, overweight, and obesity:

The prevalence of healthy weight, overweight, and obesity are shown in table 2 by sex and race-ethnic group, based on data from NHANES III (1988–94). NHANES provides estimates for three major race-ethnic groups: non-Hispanic white, non-hispanic



Hispanic black, and Mexican American, as well as for the total population including all race-ethnic groups. In the total population, the prevalence of healthy weight was higher overall for women than for men, but within race-ethnic groups this was true only for non-Hispanic white women. The prevalence of overweight (BMI 25–29.9) was higher for men than for women, but the prevalence of obesity (BMI 30 or greater) was lower for men than for women. The prevalence of overweight and obesity was lower for non-Hispanic white women than for non-Hispanic black or Mexican-American women.

B. Ideal body fat percentage

IDEAL BODY FAT PERCENTAGE CHART
(American Council on Exercise)

Description	Men	Women
Essential fat	2-5%	10-13%
Athletes	6-13%	14-20%
Fitness	14-17%	21-24%
Average	18-24%	25-31%
Obese	25%+	32%+

The chart above from the American Council on Exercise (ACE) is one of the most commonly used body fat charts. As you can see, women have a higher body fat percentage relative to men for a given level. Women have more fat because of physiological differences such as hormones, breasts, and sexual organs. In addition, women need a higher amount of body fat for ovulation.
"Essential fat" is the minimum amount of fat necessary for basic physical and physiological health. There is a lot of controversy over what amount of body fat is optimal for overall health. A research paper by Gallagher et. al. in the American Journal of Clinical Nutrition (2000) came to the conclusion that certain low body fat ranges are "under fat", which implies "unhealthy".2 According to this research paper, men who arebetween 20-40 years old with under 8% body fat are considered "under fat", whereas a "healthy" range is described as between 8-19%. For women in this same age group, any level under 21% is "under fat" and 21-33% is considered "healthy".

C. BIA and its relevance in identifying the body fat:
An alternating current applied to human body flows through the body fluid which has very low electrical resistance. Bio-impedance is an electrical property shown by tissues in human body when electric potential is applied to it. The bio-impedance technique identifies two different types of constituents of human body. Accordingly, human body consists of highly conductive tissues in the form of body water. The other constituent is in the form of body fat which forms a less conductive part of human body. Total impedance offered by human body depends on the proportion of highly conductive and less conductive parts of the body and hence the technique is known as bioelectrical impedance analysis [1]. Bio-impedance analysis can be applied to a variety of constituents of human body including blood samples. Presently, a standard method of blood sample analysis

is used for checking blood components to diagnose blood sample infection. But this method has many disadvantages. Frequent blood sampling may result into injuries to subcutaneous tissue, subsequently reason to delusional anemia. It can also lead to inflammation, increase in regional temperature, fever, activation of phagocytes. Impedance measurement has acquired importance because of its non-invasive nature of measurement. Change in environment conditions have less effect on this kind of measurements. Use is at ease while these measurements are going on.

II. LITERATURE SURVEY

Young people generally become overweight or obese because they don't get enough physical activity in combination with poor eating habits. Genetics and lifestyle also contribute to a child's weight status. There are a number of steps you can take to help prevent overweight and obesity during childhood and adolescence. They include:
Gradually work to change family eating habits and activity levels rather than focusing on weight. Change the habits and the weight will take care of itself. Be a role model. Parents who eat healthy foods and are physically activity set an example that increases the likelihood their children will do the same. Encourage physical activity. Encourage children to eat only when hungry, and to eat slowly.

A. Preventing Obesity in Adults:

Many of the strategies that produce successful weight loss and maintenance will help prevent obesity. Improving your eating habits and increasing physical activity play a vital role in preventing obesity. Eat five to six servings of fruits and vegetables daily. A vegetable serving is one cup of raw vegetables or one-half cup of cooked vegetables or vegetable juice. A fruit serving is one piece of small to medium fresh fruit,one-half cup of canned or fresh fruit or fruit juice, or one-fourth cup of dried fruit.
Choose whole grain foods such as brown rice and whole wheat bread. Weigh and measure food to gain an understanding of portion sizes.

B. Weigh yourself regularly:

Avoid foods that are high in "energy density" or that have a lot of calories in a small amount of food. For example, a large cheeseburger and a large order of fries may have almost 1,000 calories and 30 or more grams of fat.
Crack a sweat: accumulate at least 30 minutes or more of moderate-intensity activity on most, or preferably, all days of the week. Examples include walking a 15-minute mile, or weeding and hoeing the garden.

III. METHODOLOGY

Bio-electric impedance analysis is based on measuring the electrical resistance of the human body.

Via electrodes on one hand and foot, a weak, imperceptible electrical field is generated inside the body by means of an impedance analysis device.

A BIA analysis consists of 2 work steps:

-Measurements are taken from the prone patient using the BIA device. The patient should remove sufficient clothing to allow a gel electrode to be attached to the hand and foot. The measuring instrument is then connected to the electrodes and the measuring routine is started. Depending on how much clothing the patient takes off, this procedure takes approximately 1 to 2 minutes.

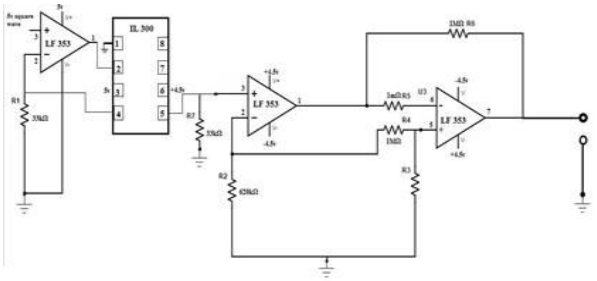
-Entering the figures into the formula, and calculating the results.

Total time needed for the measuring routine and printing out the results: approximately 2 to 3 minutes.

The measurement of body fat is best taken when the electrodes are placed at the wrist and the contralateral ankle. When measuring the impedance of the cellular tissue, we model it as a resistor in parallel with a resistor and capacitor in series. In this model the single resistor

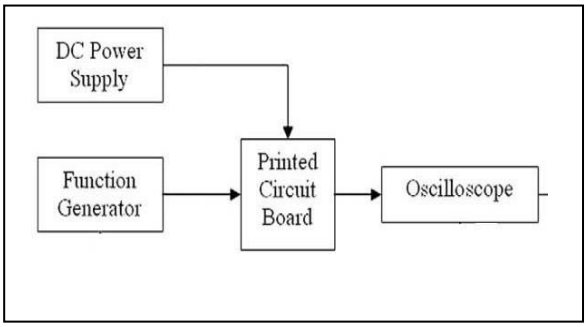
represents the extracellular path and the resistor and capacitor in series represents the intracellular path.

This model shows a change in impedance with respect to the frequency of the AC current. By injecting an AC current through one's body and measuring the voltage across the electrodes, we can easily find theinstantaneous impedance. This project requires a current to go through one's body which is dangerous so it is imperative to generate a small AC current through the two electrodes, possibly on the order of 10 μA.
A major part of being able to determine body fat involved determining how the impedance information collected from the circuit related to the subject's body fat. To create the body fatequations, we used the volunteer body fat, voltage, age, and weight data.



A. *BLOCK DIAGRAM*

The above block diagram represents the basic construction of a Bio-Impedance Analysis experiment setup.The main components of this setup are as shown in the above figure 3.4 are:
- DC power supply
-Function generator
-Main circuit
-Oscilloscope.



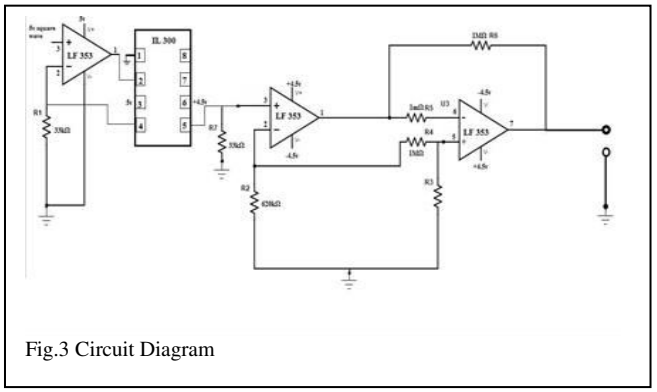


Fig.3 Circuit Diagram

Fig.4 Block Diagram of BIA

B.EQUATIONS:

Male:

Body fat = 0.0923 * *weight* + 0.1605 * *age* - 0.0263 **voltage*

Female:

Body fat = 0.1871 * *weight* + 0.5800 * *age* - 0.0920 * *voltage*

IV.RESULT

A. OBTAINED RESULT:

1. Readings obtained: female subjects

Female:
Body fat = 0.1871 * weight + 0.5800*age - 0.0920* voltage

Table.1 Readings attained:*female subjects*

NAME	AGE*	WEIGHT	VOLATGE	FAT%
SUBJECT 1	21	54	0.4	22.24
SUBJECT 2	21	50	0.5	21..48
SUBJECT 3	21	60	0.2	23.38
SUBJECT 4	21	40	0.8	19.59
SUBJECT 5	21	58	0.4	22.99
SUBJECT 6	21	40	0.8	19.59
SUBJECT 7	21	59	0.2	23.20
SUBJECT 8	20	50	0.6	20.89
SUBJECT 9	22	47	0.5	21.50
SUBJECT 10	20	40	0.9	19
SUBJECT 11	21	43	0.6	20.17
SUBJECT 12	23	54	0.4	23.40
SUBJECT 13	23	40	0.8	20.75
SUBJECT 14	20	50	0.5	20.9

[*ABOVE SUBJECTS BELONG TO THE AGE GROUP OF 20-23]

2. *Readings obtained: male subjects*

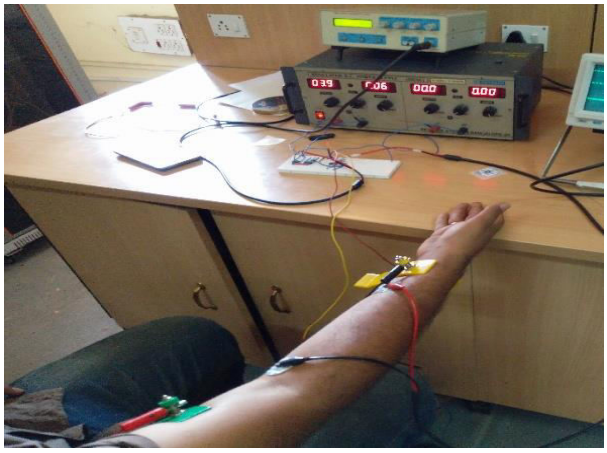
Male:

Bodyfat = 0.0923 * weight + 0.1605 * age - 0.0263 * voltage

Table.2 Readings attained: male subjects

NAME	AGE*	WEIGHT	VOLTAGE	FAT%
SUBJECT 1	20	65	0.6	9.35
SUBJECT 2	21	67	0.5	9.54
SUBJECT 3	22	85	0.1	11.37
SUBJECT 4	20	66	0.6	9.44
SUBJECT 5	20	78	0.2	10.40

[*ABOVE SUBJECTS BELONG TO THE AGE GROUP OF 20-23]



The above result is in the tabulated [Table-1 and 2] format, the voltage values obtained during the examination of subjects are substituted in a pre-defined formula which helps us in determining body fat percentage.

On comparing the above tabulated values with Fig.2 Ideal Body Fat Percentage chart (American Council on Exercise).
We can conclude that out of fourteen *female subjects* seven are fit and seven belong to athlete category. Whereas, out of six *male subjects*all the six subjects belong to the athletes category.

The body fat percentage differs with respect to gender and race.

V.CONCLUSION

It is a non invasive easy and quick method, technically uncomplicated methodand also helps people to be aware if their own body composition. It enables catabolic processes to be detected at an early stage and assess whether hydration is abnormal or not.

The paper uses American standard as per the equation above and hence may not be appropriate in generalising it across all geographical borders.

VI.REFERENCES

1] D. Biswas, K. Pal, U. Kumar, and D.N. Tibrewala, Development of low cost bio impedance analyser for analysing various biological samples, *in International Conference on Communications, Devices and Intelligent Systems (CODIS), Kolkata.*

[2] A research paper by Gallagher et. al. in the American Journal of Clinical Nutrition(2000)

[3] M.A. Kadir, K.S. Rabbani, and A.J. Wilson, Development of a multi-frequency system for medical applications of focused electrical impedance method (FIM) appropriate for developing countries*in 7th International Conference on Appropriate Healthcare Technologies for Developing Countries, London.*

[4] R.S Khandpur-*Biomedical-Instrumentation Handbook(2002edition)*

[5]M. K. B. Kishore, V. Sapthagirivasan, V. K. Manohar and M. Anburajan, "Total body composition measurement by using bioelectric impedance analysis and its impact on obesity," *Electronics and Information Engineering (ICEIE), 2010 International Conference On*, Kyoto, 2010, pp. V1-96-V1-99. doi: 10.1109/ICEIE.2010.5559846

[6]N.I. Khramtsova and S. A. Plaksin, "Two-electrode bioelectrical impedance measurement in body composition analysis before and after liposuction," *2016 IEEE International Symposium on Medical Measurements and Applications (MeMeA)*, Benevento, 2016, pp. 1-5. doi: 10.1109/MeMeA.2016.7533701