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Research paper



A cognitive study of body fat percentage in humans by anatomization of LIPID profile, bio-electric impedance and clustering using k-means algorithm

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Abstract

The pathogenesis of obesity and overweight delves fathomlessly into a person's physical activities, food habits and their genetic inheritance. Infelicitously a substantial number of population have moved to urbanization with shifts towards less physical work, exercise and diets high in saturated fats and sugars paving the way for the soaring rise in corpulence amongst individuals. Multifarious prodigious stud-ies have been done on the perennial concerns caused due to obesity. Due to the scathing health lurgies that have originated in recent times, a punctilious exploration of body fat percentage for an individual has become imperative. The quondam work anent body fat percentage in-volved a formula comprising of Body Mass Index (BMI), age and gender of a person. The anatomical conformation of an individual unrav-eling the fat constitution, and the muscle-tissue composition is not construed by using BMI. Thus the formula dampers the veracity for a person having more muscle mass than fat mass, and speciously vitiates the fat percentage of that person. The proposed study escalates the coherence and efficacy of the body fat percentage for a person by entailing the lipids from the blood test, the subcutaneous and the visceral fat values obtained from a Bio-Electric Impedance method in the formula. The ethical committee approval for this study has been obtained from the Institutional Ethics Committee, Madras Medical College, and Chennai. This pragmatic study has been statistically analyzed using R-tools and the results have been successfully acquired.

Keywords: *Obesity; Body Fat Percentage; BMI; Bioelectric Impedance; R-Tools*

1. Introduction

Obesity and its concomitant malaises have been extensively studied in the furcated branch of Medical Science known as Bariatric. The inflated dismays of obesity are expatiated with a lot of cognizance being raised in many parts of the world. In a study conducted by the World health Organization (WHO) in the year 2014, it has been found that more than 1.9 billion adults who were 18 years and older were considered overweight. Amongst these over 600 million were obese. Most of the world's population lives in countries where overweight and obesity kills more people than underweight. The study organized by WHO also showed that 41 million children under the age of [5] were overweight or obese [5], [19]. A neoteric and unabating realm in the health industry is the advancement in bariatric sector. The stage of life a person becomes obese can transmute the ability of the person to lose weight. The energy imbalance between the ingested calories and the calories expended is considered as the Fon ET origo of obesity and uncurbed fat [19].

Obese individuals can have great difficulty losing weight. The uncurbed energy and WAT can cause serious detriments like Cushing's syndrome, Hypothyroidism, Neurologic disturbances and various other health impediments [9] , [19]. Though dieting and exercise are solutions for weight reduction, studies show that only the size of the fat cells are pruned, instead of annihilating them completely [4], [19]. To anatomize the growth of adipose cells in the human body a meticulous analysis about the White Adipose Tissue (WAT) and Brown Adipose Tissue (BAT) is done.

Brown Adipose Tissue (BAT) are an important integrant which proselytizes the excessive fat in the body by incinerating them [6], [7], [19]. They comprise of several lipid droplets, with ginormous quantum of iron. On the other hand, WAT consists of a single lipid droplet, less mitochondria, and are regarded as the unbridled, unseared body fat which usually leads to obesity and other diseases [8], [19]. In children, the excess calories and WAT are converted into new fat cells (hyperplasic obesity) [1], [2, [19], while the nimiety of calories consumed by an adult proliferates the existing fat cells (hypertrophic obesity) [4], [19].

The body fat percentage is a cardinal factor that connotes if a person is healthy or not. Body fat is primarily divided into two categories such as the subcutaneous fat and the visceral fat [11], [13], [19]. Subcutaneous fat is that which is located beneath the skin [11], [19], while the visceral fat is located inside the peritoneal cavity surrounding the peritoneal organs [12], [19]. The various approaches for treating obesity incorporate studies of hormones like Leptin and Ghrelin. These hormones are secretions of the fat cells in the body. Leptin is concomitant to the reproductive function, and Ghrelin stimulates the pituary gland to release growth hormones. Hyperlipidemia and proliferation of fat are often analogized as they correlate and aid in procuring better cognizance of obesity disorders.

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The previous work of study involved the assessment of BMI for an athlete or a healthy person with more muscle mass can lead to fallacious results. This paper aims to ascertain the need for an empirical computation of body fat related to an individual's lipid profile and the subdivided fat values [19]. Thereby assimilating the blood lipid levels for High-density Lipoprotein (HDL), Low density Lipoprotein (LDL), Triglycerides (TG), Total Cholesterol (TC) and the subcutaneous, visceral fat percentage obtained using bioelectric impedance method [10], [13], [19]. This formula and analysis may meliorate the accuracy of body fat percentage and may aid in providing viable results for obese patients in future [19]. The paper is organized as follows: Section II gives a brief study of the techniques implemented, and the factors obtained from it. Section III elucidates the use of the derived formula for body fat percentage. Section IV delineates the correlation relation between the various factors and the results obtained from the correlation analysis using R tool, Section V concludes the work done with the future work that can be implemented.

2. Techniques used

The study population includes adult patients who were obese, hyperlipidemic and faced other problems due to unbridled disintegration of energy. The data samples were garnered from Rajiv Gandhi Government General hospital, Park Town, Chennai. In this paper, the body fat percentage is computed by formulating the values obtained from the blood tests and the bioelectric impedance method for a person [19]. Pregnant women, patients having bleeding disorders, patients who are anaemic and suffer from any other serious ailments were excluded from the study [19].

2.1. Lipid profile tests

The baseline investigations include 4 - 5 ml of blood collected from patients who fasted for 9-12 hours before having the blood sample drawn. The blood sample obtained is checked for the lipid levels such as Total Cholesterol (TC), High-density Lipoprotein (HDL), Low density Lipoprotein (LDL) and Triglycerides (TG), which are centrifuged and then combined with the Cfas lipid reagent along with the necessary precicontrols to acquire the values of each.

2.2. Bio - electric impedance analysis

The Bioelectric Impedance analysis (BIA) is a non- invasive method. It employs a technology which is extensively used, and aids in providing impeccable analysis of the body composition for an individual [15], [19]. It operates at a temperature humidity of 5 to 35 degree Celsius with no corrosive gas in the surrounding air. Bioelectric Impedance expounds as the opposition of a conductor to the flow of an alternating current, and consists of two constituents: resistance (R) and reactance (Xc) [17], [18], [19].

Resistance has a low frequency of 40-50 kHz and is the radical opposition of the conductor [18]. Reactance is the additional opposition or the ephemeral storage of the electric charge by a condenser. The lipid components of the membranes of the Body Cell Mass (BCM) behave as capacitors and reduce the flow of intracellular ions [18], [19]. Despite a general perception that BIA estimates body fat, the technology actually determines the electrical impedance of body tissues and adiposity [16], [19]. The BIA quantifies the resistance of body tissues through the flow of small electrical signals through the ions present in the fluid content of a human body. The device uses a pair of electrodes through which a low level imperceptible electric current flows and divulges the estimates of water content and body fat in the blood, tissues and bones. The fat in the body is analyzed depending on where they are distributed. The electric current which passes through the body is at differential rate depending on the body composition [18], [19]. Hence there is a direct relationship between the concentrations of the ions and electric conductivity, and an indirect relationship exists between the ion concentration and the resistance [18], [19].

The BIA enumerates and itemizes the body facets such as visceral fat percentage, subcutaneous fat percentage and segmental subcutaneous fat percentage, age of the individual cognate to their fat percentage, Body Mass Index (BMI), muscle mass percentage, its corresponding segmental muscle mass percentage and the total body fat percentage [19]. The BIA is currently used in diverse settings including private clinics, hospitals and across a spectrum of ages, body weights and disease states [19].

2.3. K-Means algorithm

Clustering is the technique of amassing data objects into dissipated clusters so that the data in the same cluster are homogenous, but data belonging to different cluster are disparate. K-Means is the most popular partitioning method of clustering. K-Means algorithm follows two phases:

i) Select K- centroids randomly,
ii) Each object in the dataset is associated to the nearest centroid.

The input for the algorithm is given as the name of the dataset followed by the number of clusters to be partitioned. This study comprised of two clusters: Normal and Obese. The patients having a Body fat percentage equal to and below 30 were categorized into the Normal cluster. Patients having a body fat percentage above 30 were categorized into the obese category.

The results show the attributes like sum of the squares within the clusters, the cluster sizes and the cluster means implicitly defined. The algorithm works as follows: Capriciously determine the value of K from dataset D which enumerates the desiderated number of clusters. The next step would be to delegate each data item to the cluster with elevated homogeneity based on the mean value of the object in the cluster. The new cluster mean after each reassignment is emended. Repeat the above step until no change.

3. Explication of the derived formula

The existing body fat formula is given as:

[(1.2*BMI) + (0.23*Age) – (10.8*Gender) – 5.4] [14], [19]

Though the above formula has been widely accepted as the standard measure to analyze body fat percentage, it has been observed that for a person who is muscular and has more muscle mass, the BMI increases considerably, thereby placing him/her in the morbidly obese or overweight category [19]. Therefore to avoid fallacious calculations, the below formula involving the Total Cholesterol (TC) from the lipid profile, subcutaneous and visceral fat from the BIA, age pertaining to the fat accumulation in the body and gender of the person is taken into consideration. The optimal feasible formula thus obtained is as follows [19]:

$$\text{Body fat \%} = [(1.2*(SF+VF)) + (0.23 * (Age\ (M) - Age)) - (0.094*TC) - (4.5*Gen) + 5.4] \quad (1)$$

Where SF & VF signifies the subcutaneous and the visceral fat, age (M) is the age of the person with respect to the body fat percentage, gender (Gen) takes the value of [0] for female and 1 for male [19].

4. Results obtained

An analysis has been performed to vindicate and augment the derived formula. The correlation between the various factors such as the combined values of SF+VF, the body fat percentage and the Low-Density Lipoprotein (LDL) has been reckoned. Nextly, the Pearson's Correlation analysis has been implemented to find the correlation estimate. The Correlation analysis quantifies to a posi-

tive correlation which indicates that there is a distinctive proliferation of fat percentage in the body when there is an increase in the weight of the person, the LDL value and the fused values of subcutaneous and visceral fat.

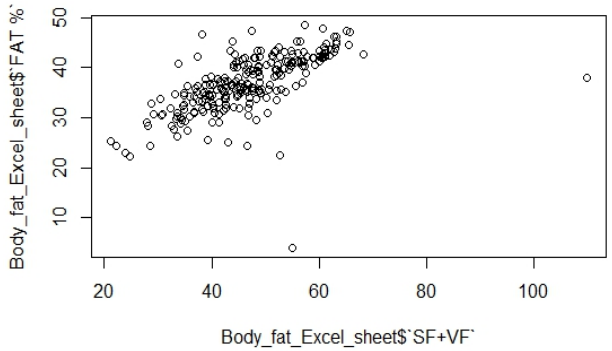


Fig. 1: Correlation of Fused Values of Subcutaneous & Visceral Fat Values with Body Fat Percentage.

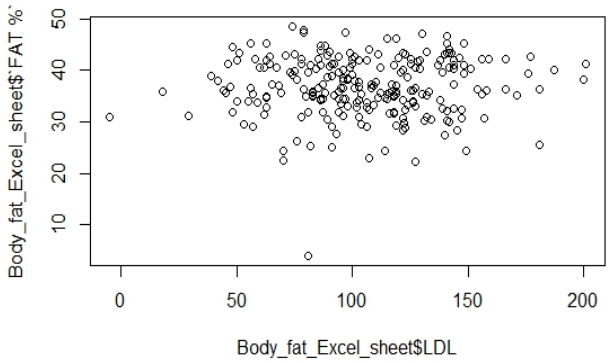


Fig. 2: Correlation of Low-Density Lipoprotein (LDL) with Body Fat Percentage.

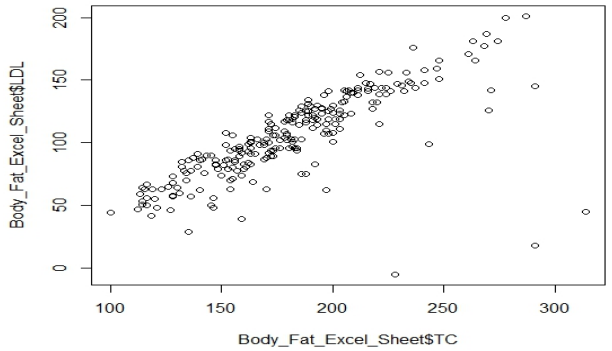


Fig. 3: Correlation of Total Cholesterol (TC) with Low Density Lipoprotein (LDL).

The K-Means Algorithm implemented in R-Tools displayed the below result, Where S1 is the alias name assigned for the dataset Body_fat_Excel_Sheet and clustered into two groups: Normal and Obese.

```
> Result <- kmeans (S1, 2)
> Result
K-means clustering with [2] clusters of sizes 225, 14
```

Table 1: Cluster Means

AGE	H (m)	W(k)	TC	LDL	SF+VF	Feasible Using TC
39.38	1.54	76.23	154.12	81.79	47.21	50.78
43.23	1.55	75.11	214.03	133.01	45.94	43.21

```
Clustering vector:
[1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1
[38] 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
[75] 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
[112] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
[149] 1 1 1 2 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 2 1
[186] 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1
[223] 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 2
Within cluster sum of squares by cluster:

[1] 1761154.0 603361.2 (between_SS / total_SS = 66.5 %)
```

5. Conclusion

This study has aided the facilitation and revamped the computation of body fat percentage using the values obtained from the lipid profile of a person instead of using BMI. The subcutaneous and visceral values have been orchestrated to impart a deeper cognizance as they contour the basis of analyzing a person's intramural and over the skin fat depositions. The derived formula has yielded a mean error rate of less than 0.4%. The K-Means algorithm has effectuated and capacitated the grouping of homogenous classes using a threshold value for the body fat percentage. Thus the derived formula can be contemplated as an unambiguous and unswerving measure to be used in the future to meliorate the health calibre.

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