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Accuracy of Body Mass Index in Diagnosing Adiposity Compared To Body Fat Percentage Measured By Bioelectrical Impedance in Adults at Al-Najaf Governorate

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Abstract

Background: Obesity is defined as an excess of body fat that is sufficient to affect adversely on health. The Body Fat Percentage (BFP) of a human or other living being is the total mass of fat divided by total body mass. Bioelectrical impedance analysis has been shown to be more precise for determining lean or fat mass in humans, In comparison with body mass index, anthropometric and skin fold methods, Bioelectrical Impedance Analysis (BIA) is commonly used method for estimating body composition, and in particular Percentage of body fat . BIA is known to provide a rapid, non-invasive and relatively accurate measurement of body composition

Aim: To evaluate the accuracy of body mass index in diagnosing overweight and obesity compared to percentage of body fat measured by bioelectrical impedance.

Subjects and methods: Cross sectional study for adult population age of them range from (18-65) years of both gender selected by using systematic sampling technique from private clinic during the period (1st of March to the 1st November) 2017. For each person measured the height with a regularly calibrated Stadiometer. And according to weight was recorded by bioelectrical impedance machine then enter manually age, gender and height to bioelectrical impedance technique (in body 370 machine) that is used for estimating body composition. The data will be coded and entered into Statistical Package for Social Sciences (SPSS) version 20.

Result: A total of 711 subjects had been included in this study, the male: female ratio was 0.35: 1, the mean age of subjects was 31.4 ± 10.58 range (18-65) years there was shows high validity of BMI in detecting excess of body fat as compared to Body Fat percent as a reference test. The sensitivity was 94% and specificity was 96%. For both gender. Also There was a strong and significant positive correlation between percentage of body fat and Body Mass Index and mineral density and Body Fat Mass when $p<0.001$ in males and females. A positive correlation also was detected between percentage of body fat and age in both genders with waist hip ratio.

Conclusion: There is high validity of body mass index in diagnosing overweight and obesity but still there are false positive and false negative cases that should be encountered.

Keywords: Obesity; Body mass index; Bio-electrical impedance

Introduction

Obesity is defined as an excess of body fat that is sufficient to affect adversely on health [1]. It results from an increase intake of energy from food consumption over energy expenditure and thus both an increase in intake and a decrease in expenditure will lead to excess calories being stored as fat and ultimately to obesity. So it is more prevalent in the lower socio-economic people in developed countries and the reason for this is unknown, but may reflect food availability and marketing practices. Ethnicity of subjects also plays role in the prevalence of obesity; white men and black women are more obese than their corresponding counterparts [2]. Obesity tends to run in families but shared environmental factors (meals and level of activity) probably contribute more to obesity than common genetic factors and the current, rapid increase in obesity prevalence cannot be explained by the gene pool changing so quickly. Some individuals are genetically more susceptible to the effects of an obesogenic environment and it is associated with a higher risk of death and morbidity [3]. Obesity is like many other medical conditions, the result of an interplay factor [4]. Polymorphisms in various genes controlling appetite and metabolism predispose to obesity when sufficient food energy is present. As of 2006, more than 41 of these sites on the human genome have been linked to the development of obesity when a favorable environment is present [5]. The ideal healthy body weight for a particular person is dependent on many things, such as frame size, sex, muscle mass, bone density, age, and height additionally dependent on cultural factors and the mainstream societal advertisement of beauty [6]. Due to difficulty of measuring body fat under field conditions the practical definition of obesity for adults is based on Body Mass Index (BMI). Body mass index, also known as Quetelet's index, is calculated as an individual's weight by (kg) on square length by (m^2) [7]. Body Mass Index (BMI) was devised in year of 1830 by Lambert Adolphe Jacques quetelet, a

Belgian mathematician. No specialized equipment is required; so it is easy to measure accurately and consistently across different countries and regions. Therefore, it has been accepted as an international standard for the measurement of obesity [8]. Although the two terms overweight and obese are often used interchangeably and considered as gradations of the same thing, they denote different things [6]. National Institute of Clinical Excellence (NICE) has recommended the use of BMI measures in the management of overweight and obesity in adults [9]. According to WHO classification BMI (kg/m^2) associated health risks underweight less than (18.5) consider low (but risk of other clinical problems increased) normal range is between (18.5-24.9), overweight is between (25.0-29.9) risk is Increased, obese class I is between (30.0–34.9) moderately increased risk, obese class II is between (35.0-39.9) severely increased risk, obese class III is 40 or higher very severely increased risk [10]. The life expectancy of men and women with a BMI of >45 kg/m^2, 13 years for age of 20 and 8 years for age of 30 lower than that of those with a BMI of 24 kg/m^2 [3]. The health risks associated with increasing BMI are continuous and the interpretation of BMI gradings in relation to risk may differ for different populations. BMI values are age-independent and the same for both sexes. However, BMI may not correspond to the same degree of fatness in different populations due, in part, to different body proportions [10]. Central or visceral adiposity is a particularly strong predictor for the development of hypertension and this association is independent of BMI [11,12]. Organs like kidney, liver, and heart are more severely affected by abdominal fat than by the fat around the bottom or hips. In addition, very high muscle mass skews the BMI measures. Muscle is denser and weighs more than fat (a cubic centimeter of muscle weighs more than a cubic centimeter of fat therefore, well built, athletic people will inevitably be classed as fatter, by BMI, than they really are [13].

Waist circumference is a better appraiser of metabolic risk than BMI because it is more directly proportional to total body fat and the amount of metabolically active visceral fat [14]. It is at least a good indicator of total body fat as BMI or skin fold thicknesses, and is also the best anthropometric predictor of visceral fat [15]. A raised waist circumference is defined as greater than 102 cm in men and greater than 88 cm in women [16]. People with increased fat around the abdomen or wasting of large muscle groups, or both, tend to have a large waist circumference relative to that of the hips (high waist to hip ratio).Waist circumference alone gives a better prediction of visceral and total fat and of disease risks than waist to hip ratio Waist circumference is minimally related to height, so correction for height (as in waist to height ratio) does not improve its relation with intra-abdominal fat or ill health [15]. Waist Circumference (WC) is a valid measure of abdominal fat mass and disease risk in individuals with a BMI less than 35 kg/m^2. If BMI is 35 kg/m^2 or more, WC adds little to the absolute measure of risk provided by BMI. Therefore, WC and WHR are not routinely measured in patients with BMI greater than 35 kg/m^2 [16]. Increased body mass associated with obesity places a greater load on skeletal muscle and therefore imparts a training effect (analogous to resistance training) to increase muscle mass and strength. Evidence in support of this is that maximal leg and trunk strength, but not handgrip and arm strength, has been shown to be greater in obese than in lean individuals [17,18]. The Body Fat Percentage (BFP) of a human or other living being is the total mass of fat divided by total body mass. The body fat includes two types: essential and storage body fat, Essential body fat that is necessary to maintain life and a reproductive functions and storage fat that consist of fat accumulation in adipose tissue, part of which protects internal organs in the chest and abdomen [19]. Physically, differences in stature and shape are the first indicators that allow us to distinguish between men and women and we are biologically programmed to be acutely sensitive to these markers. In addition to size differences, at any given Body Mass Index (BMI), women generally have higher levels of total body fat and lower levels of fat-free mass and they weigh less and are shorter [20]. This gender difference reflects the differences in body fat content; body fat is practically water-free. This also means that if a person gains weight in the form of fat the percentage of total body water content declines [21]. The normal range percentage of essential fat is 2-5% in men, and 10%-13% in women [19]. Bioelectrical Impedance Analysis (BIA) is commonly used method for estimating body composition, and in particular body fat% [22]. BIA is known to provide a rapid, non-invasive and relatively accurate measurement of body composition [23]. Actually determines the electrical impedance to the flow of an electric current through body tissues which can then be used to estimate Total Body Water (TBW), which can be used to estimate fat-free body mass and, by difference with body weight, body fat [24]. Bioelectrical Impedance Analysis (BIA) is a good alternative for measurement of percentage body fat (%BF) when subjects are within normal body fat range [25]. This device is based on the fact that fat slows down the passage of electricity through the body. When a small amount of electricity is passed through the body, the rate at which it travels is used to determine body composition [6]. The studies on the electrical properties of biological tissues have been going on since the late 18th century [26] and categorized according to the source of the electricity like active and passive response. Active response (bioelectricity) occurs when biological tissue provokes electricity from ionic activities inside cells, as in Electrocardiograph (ECG) signals from the heart and Electroencephalograph (EEG) signals from the brain. Passive response occurs when biological tissues are simulated through an external electrical current source [22].

Bioelectrical impedance analysis has been shown to be more precise for determining lean or fat mass in humans [27]. Not all obese individuals have increased amounts of muscle mass. In fact, 5%-10% of the elderly are both obese and have low levels of muscle mass [28,29] a condition referred to as sarcopenic obesity. These individuals are at much greater risk for disability [30] and also mortality [31,32]. Unfortunately, individuals with sarcopenic obesity are not easily identified because they may have normal or near-normal body mass index [33]. So we studied sub population at Al-Najaf governorate to determine the accuracy of BMI in detecting obesity compared to BF %, as reference test. As obesity defined an excess of body fat and also we tried to find the effects of age and gender on this relationship.

Subject and Methods

Study design: Cross sectional study.

Setting of the study: The study were done in a private clinic at Al-Najaf governorate during the period (1st of March to the 1st of November) 2017.

Sampling technique: Systematic sampling technique (between one and another with taking the subsequent one in case of the patient was child), nearly 3 days per week.

Inclusion criteria: Subjects between (18-65) years old, both gender.

Exclusion criteria: Pregnant woman, Patient cannot stand, Woman with menstrual cycle, Person take diuretic within 7 days from time to test done.

Ethical considerations: Verbal consent had been taken from all participants.

Sample size determination

The sample was estimate according to the following equation [34]:

$n=Z^2 P(1-p)/d^2$

$n=(1.96)^2 \times 0.6 \times 0.553/(0.05)^2$

Minimal sample size required

n=397

n=Sample size

Z=Confidence interval according to the standard normal distribution 95% (1.96)

P=Estimated proportion of the participant 0.553 [35]

d=Tolerated margin of error which was selected to be 0.05

Anthropometry

For each person measures to him the height with a regularly calibrated Stadiometer. By using a horizontal arm that moves vertically on a calibrated scale, person should be stand erect in bare feet that are kept together without shoes against a straight surface with the head level. The head level should be with a horizontal Frankfort plane (an imaginary line from lower border of the eye orbit to the auditor Meatus) and according to weight was recorded by analysis then enter manually age, gender and height that measuring it beforehand [15].

Bioelectrical impedance derived percentage of body fat

In body 370 machines (In Body Bldg., 54, Nonhyeon-ro2-gil, Gangnam-gu, Seoul 06313 Korea) that is used method to estimating body composition person was measured while standing erect, in bare feet on the footpads analyzer and wearing thin clothes. Not eat or drink within 4 hrs and no exercise within 12 hrs of the test done and gently grasped the two handgrips with arms held straight forward at 90 degrees. The machine of 15 impedance measurements by using 3 different frequencies (5 kHz, 50 kHz, 250 kHz) at each 5 segment of the body (Right arm, Left arm, Trunk, Right leg, Left leg) it consists of tetra polar 8 point tactile electrode system stainless steel foot [36].

Statistical analysis

The data has been coded and entered into Statistical Package for Social Sciences (SPSS) version 20 and analyzed by using chi square, Pearson correlation coefficient in addition to calculation of Sensitivity, Specificity, PPV, NPV, LR+, LR-.

Result

A total of 711 subjects had been included in this study, the male: female ratio was 0.35: 1; the mean age of subjects was 31.4 ± 10.58 years (range 18-65). There were 188 (26.4%) males and 523 (73.6%) females (Table 1).

Variable		Frequency	Percentage
Gender	Male	188	26.4
	Female	523	73.6
Age/years	18-30	379	53.3
	31-40	183	25.7
	41-50	116	16.3
	>50	33	4.6
Diabetes mellitus		47	6.6
Hypertension		82	11.5
Asthma		12	1.7

Table 1: General demographic characteristics.

Table 2 shows high validity of BMI in detecting excess of male body fat as compared to BF% as a reference test. The sensitivity was 92% and specificity was 95%.

		PBF		Total
		High	Normal	
BMI Kg/m^2	≥ 25	99	4	103
		96.1%	3.9%	100.0%
	≤ 25	8	77	85
		9.4%	90.6%	100.0%
Total		107	81	188
		56.9%	43.1%	100.0%
BMI: Body Mass Index; PBF: Percentage of Body Fat; Sensitivity:=92%; Specificity=95; Positive predictive value=96%; Negative predictive value=90%; Positive Likelihood Ratio=18.736; Negative Likelihood Ratio=0.079				

Table 2: Accuracy of body mass index compared to percentage of body fat among males.

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Table 3 shows high validity of BMI in detecting excess of female body fat as compared to BF% as reference test. The sensitivity was 95% and specificity was 97%.

		PBF		Total
		High	Normal	
		341	4	345
	≥ 25	98.8%	1.2%	100.0%
		16	162	178
BMI	≤ 25	9.0%	91.0%	100.0%
		357	166	523
Total		68.3%	31.7%	100.0%
Sensitivity=95%; Specificity=97%; Positive predictive value=98%; Negative predictive value=91% Positive Likelihood Ratio=39.640; Negative Likelihood Ratio=0.046				

Table 3: Accuracy of body mass index compared to percentage of body fat among Females.

There is high validity of BMI in detecting excess of body fat as compared to BF% when the sensitivity was 94% and specificity was 96% as shown in Table 4.

		PBF		Total
		High	Normal	
		440	8	448
	≥25	194.9%	5.1%	200%
		24	239	263
BMI	<25	18.4%	181.6%	200%
		464	247	711
Total		125.2%	74.8%	200%
Sensitivity=94%; Specificity=96%; Positive predictive value=98%; Negative predictive value=90% Positive Likelihood Ratio=29.278; Negative Likelihood Ratio=0.053				

Table 4: Accuracy of body mass index compared to percentage of body fat for all participants.

Table 5 Shows significant association between age of the subject and BF%, when p<0.001

		PBF male		Total	χ^2	p value
		High	Normal			
		20	59	79		
	18-30	25.30%	74.70%	100.00%		
		51	8	59		
	31-40	86.40%	13.60%	100.00%		
		16	14	30		
	41-50	53.30%	46.70%	100.00%		
Age/years	>50	20	0	20	68.439	<0.001
		100.00%	0.00%	100.00%		
		107	81	188		
Total		56.90%	43.10%	100.00%		

Table 5: Relation between age and PBF among males.

There is significant association between age of the subject and BF% (p<0.001) as shown in Table 6. Table 7 Shows significant association between age of the subject and BMI when (p<0.001).

		PBF female		Total	χ^2	p value
		High	Normal			
		157	143	300		
Age/years	18-30	52.30%		100.00%	84.462	<0.001

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		107	17	124		
	31-40	86.30%	13.70%	100.00%		
		82	4	86		
	41-50	95.30%	4.70%	100.00%		
		11	2	13		
	>50	84.60%	15.40%	100.00%		
		357	166	523		
Total		68.30%	31.70%	100.00%		

Table 6: Relation between age and PBF among Female.

		BMI		Total	χ^2	p value
		BMI ≥ 25	<25			
		20	59	79		
	18-30	25.30%	74.70%	100.00%		
		47	12	59		
	31-40	79.70%	20.30%	100.00%		
		16	14	30		
	41-50	53.30%	46.70%	100.00%		
		20	0	20		
Age/years	>50	100.00%	0.00%	100.00%	58.966	<0.001
		103	85	188		
Total		54.80%	45.20%	100.00%		

Table 7: Relation between age and BMI among males.

Table 8 shows significant association between age of the subject and BMI (p<0.001). There was a strong and significant positive correlation between BF% and BMI and mineral density and BFM when p<0.001 in females as shown in Table 9. In Table 10 there was a strong and significant positive correlation between BF% and BMI and mineral density and BFM when p<0.001 in males.

		BMI Kg/m^2		Total	χ^2	p value
		≥ 25	<25			
		149	151	300		
	18-30	49.70%	50.30%	100.00%		
		105	19	124		
	31-40	84.70%	15.30%	100.00%		
		82	4	86		
	41-50	95.30%	4.70%	100.00%		
		9	4	13		
Age/years	>50	69.20%	30.80%	100.00%	87.97	<0.001
		345	178	523		
Total		66.00%	34.00%	100.00%		

Table 8: Relation between age and BMI among females.

Variable	r	p value
BMI Kg/m^2	0.844	<0.001
BFM kg	0.803	<0.001
r=correlation coefficient; BFM=Body Fat Mass		

Table 9: Correlation between Percentage of Body Fat and BMI, BFM among males.

Variable	r	p value
BMI Kg/m^2	0.779	<0.001
r=correlation coefficient; BFM=Body Fat Mass		

Table 10: Correlation between percentage of body fat among females and different variable's.

Discussion

Overweight and obesity are the fifth leading risk for global deaths this leading to at least 2.8 million adult deaths each year [37]. An increase in the prevalence of overweight and obesity is expected over the next two decades, also the prevalence of obesity has increased in high and low income countries but high income countries, obesity affects mainly the less advantaged population [38,39]. And in developing countries, obesity prevalence is greater in the higher income population [40]. The use of BMI as a measure of excess body weight may lead to some misclassification as it does not distinguish between fat and muscle mass [41]. The body fat percentage is a measure level; it is the only body fitness of measurement which directly calculates a person's relative body composition without regard to height or weight [42]. So in our study we use bioelectrical impedance which is a simple instrument for estimating body fat [22]. BIA is reasonably accurate for measuring groups in an individual over a period of time [43]. The present study shows the frequency of obesity and overweight according to socio-demographic variables related to gender and age group and some chronic morbidity will be used as baseline to analyze the evolution of this morbidity for 711 adult from population living at Al-Najaf governorate. Female to male ratio was (0.35:1), age of them range from (18-65 yrs). In the current study, there was high accuracy of body mass index which was observed in males, that shows the sensitivity was 92% and the specificity was 95% and in female also shows high validity of BMI in detecting obesity and overweight as compared to BF%. The sensitivity was 95% and specificity was 97% and when take over the all males and females we see also high validity of BMI, the sensitivity was 94% and the specificity was 96% this study had some differences when compare with study of Singapore on 2012 represents a BMI had overall poor sensitivity (48.7%) and good specificity (95.7%) to detect BFP-defined obesity. After stratifying by gender, it was found that BMI had good sensitivity in males (82.6%), but only 34% sensitivity in females. On the other hand, the specificity was good for both genders, being 92.6% and 100.0% for males and females, respectively due to BMI standards in

Singapore, which were revised in 2005, overweigh was BMI >23.0 kg/m^2 and obesity was BMI >27.5 kg/m^2 [44].

Also when we measure it using correlation the result has been showed there was a strong and significant positive correlation between BF% and BMI in males was (r=0.844, p<0.001) and in female was (r=0.779, p<0.001) this result was similar to study in Siri Lanka 2013 in this research they depend on correlation and the study has been showed a strong and significant positive correlation between BMI-BF %, in males were (r=0.75, p<0.01) and also in females were (r=0.82, p<0.01).And in both male and females correlations calculated for the three different age groups of adults separately, also showed significant positive correlation when (p<0.01). They were, r =0.79/ 0.84 in (young), r=0.71/0.70 in (middle age), and in r =0.59/0.075 in (elderly) respectively [45]. Also our study was similar to result of study in a group of Saudi Arabian Adults in 2017 has been showed a significant positive correlation was observed between BMI-BF%, in males (r=1, p<0.05) and in females (r=0.9, p<0.05) of all ages [46]. Also see that study of Iran on 2013 that deal with women with multi age group has been showed BMI and Total body fat percent were strongly and significantly correlated when (Beta=0.194, p-value<0.00) [47]. When measure relationship between body fat percent and age group shows significant association between them so with increase age there is increase in body fat percent in male (p<0.001, χ^2=68.439) and in female (p<0.001, χ^2=84.462) this result is similar to study in Siri Lanka 2013 has been showed In both males and females BF% showed an increase with age with a positive linear correlation (males r=0.47, females r=0.64; p<0.000). Females of all ages had significantly higher total body fat than males (p<0.001) the mean difference in BF% between females and males was 10.44 [45]. And when see the study that occur in Iran on 2013 which deal with women with multiage group, we see correlation study of age with body fat percentage showed a weak but significant association (Beta=0.194; p value=0.00) [47]. And this result supported by study of Vietnam on 2015 that showed age and gender were also statistically associated with Percentage of body fat [48]. Also regard to relation between age and Body mass index shows significant association between age of the subject and BMI so with increase age BMI increase for both males and females, in male (p<0.001 and χ^2=58.966) and more in female (p<0.001 and χ^2=87.970) this result similar to study of city in Northeastern Brazil in 2006 has been showed overweight (BMI ≥ 25 kg/m^2) and obesity (BMI ≥ 30 kg/m^2) increased with age group which more prevalent [49]. In addition, similar to study of Iran on 2013 of women with multiage group, when evaluate of the correlation between age and Body Mass Index showed that BMI of women increased (p value=0.002) for each year of increment in age [47]. The prevalence of overweight and obesity measuring by BMI was increased with age in both genders that result of study of Vietnam on 2015 [48]. The relationship between body fat percent and bone mineral density, in our study shows there was a strong and significant positive correlation between BF% and mineral density in males (r=0.771, p<0.001) and in female (r=0.175, p<0.001) and also according to relationship between BF% and BFM, in males (r=0.803, p<0.001) and in females (r=0.736, p<0.001) this result was similar to study in china 2015 has been showed Increase Fat mass and BF% were positively associated with arm, trunk, and pelvic body mineral density in Chinese obese females. And Increased FM was positively associated with total, rib, and trunk BMD in Chinese obese males [50]. Regarding to correlation between Body fat percentage and Waist hip ratio in our study for males show significant positive linear correlation between them (r=0.841, p<0.001) and also in females (r=0.696, p<0.001) this result was similar to study in stanbul, Turkey 1999 the study shows PBF was positively correlated with Waist Circumference(WC) (r=0.73, p>0.000), and WHR (r=0.45, p>0.000) in adult females to know the fact Both WHR and waist circumference have a stronger correlation with cardiovascular risk factors [51]. Also similar to study of Brazil 2010 related to relation between Anthropometric Indicators and Risk Factors for Cardiovascular Disease has been showed positive Correlation between body fat percentage and Waist hip ratio in males (r=0.619, p<0.001) and in female (r=0.664, p<0.001) [51].

Conclusion

- There is high validity of Body mass index compared to percentage of body fat as reference sensitivity and specificity which influenced by age and gender.
- There was a strong and significant positive correlation between PBF and mineral density and Body fat mass for both gender.
- The Waist hip ratio was positive correlate with body fat percent that influenced by age and gender.

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