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Percentage of Body Fat versus Body Mass Index in Diagnosing Obesity

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ABSTRACT

Background: *Body mass index (BMI) is a common method for diagnosing obesity, however, whether its results regarding excess adiposity is correct remains debatable. Bioelectrical impedance analysis (BIA) gives a direct estimation of body fat percentage (BF%) which may more accurately represent obesity prevalence.* ***Objective***: *To assess the diagnostic accuracy of BMI in identifying obesity in comparison with BF% assessed through BIA in a sample of Iraqi adults.* ***Methods***: *A cross-sectional study was completed with 200 adults (100 males, 100 females) aged 18-60, recruited from the Nutrition Clinic at Al-Sader Medical City in Al-Najaf, Iraq. Anthropometrics were taken, and BF% was measured using an InBody 370 BIA machine. Obesity was classified as BF% > 28% for females and > 20% for males. BMI were classified using the ≥30 kg/m² and ≥25 kg/m² cut-offs to test the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).* ***Results***: *At BMI ≥30 kg/m², obesity prevalence was 30% in males and 36% in females. In comparison to BF% measured obesity, prevalence was higher at 56% in males and 58% in females. Both males and females aged over 30 and overweight by a scale of 30kg/m2 were recorded to have a high degree of specificity (100%) but a low degree of sensitivity (53.6% in males and 62.1% in females). When the criteria were changed to a BMI of 25 kg/m2, there was an increase in overall sensitivity to 84.2% with little loss of specificity (95.3%).* ***Conclusion***: *Muscle and fat mass are generally differentiated with little precision when the BMI is in the middle range. Although there is a positive correlation between BMI and BF %, the classification of non-obese people with excess body fat as non-obese is significant. BMI is still a useful tool to gauge the extent of obesity in a population, but there have to be better methods to support the recorded figures.*

Keywords: Body Fat Percent, Body Mass Index, Obesity, Diagnosing.

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INTRODUCTION

The problem of obesity continues to be a significant global concern, as its prevalence keeps increasing. Per the World Health Organization, there were over 1.9 billion overweight or obese adults as of 2016; a figure which constitutes a 3x increase to the 1975 figure, as well as around 7% of global deaths in 2015 overweight or obese (1, 2). The existence of obesity as a global concern and its increase in prevalence has not become less worrying. In 2016, the World Health Organization reported that over 1.9 billion adults were overweight or obese, a figure that is three times greater than the number recorded in 1975 and that, in 2015, about 7% of the world's population was classified as obese (1, 2). For over 40 years, the legislated obesity classification system for the Body Mass Index (BMI) has been the most universally adopted. It was in the 19th century that the definition was constructed, which involves a simple arithmetic operation of a person's weight (in kilogram) and a person's height (in meters) squared (3). Health practitioners as well as researchers who undertake epidemiological

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studies use the approach, since it is much cheaper than other methods and as a means of obesity for weight and public health control (4-6). The positive effects of Body Mass Index do not arise without considerable costs. Numerous studies have shown that in terms of morbidity and mortality associated with cardiovascular disease, being overweight or mildly obese had equal and, at times, more favorable survival outcomes compared to those with normal body mass index (7-12). This phenomenon, termed" obesity paradox," highlights the issue of lean mass vs. fat mass classification in which substantial misclassification of obesity and its consequences is bound to occur (13-15). In this context, techniques to estimate body fat percentage (BF%) such as bioelectrical impedance analysis (BIA) were developed as a means to avoid this issue. The critical difference is that while BIA is much more useful than BMI, BIA is predominantly aimed at resolving the adipose tissue and lean tissue paradox (16,17). The clinical definition of the term obesity carries considerable clinical implications, justification of which is still scant in literature. Some patients living with obesity but with a BMI labeled as "normal" or "overweight" remain undiagnosed and untreated which heightens the risk of developing cardiovascular and metabolic diseases (18,19). Conversely, people with more muscle mass and thus a higher BMI, might be erroneously classified as obese. In these cases, the patients might be exposed to the burden of undue negative healthcare and psychological stress which, in turn, decreases their confidence in the healthcare system (20,21). In the modern world, it is crucial to assess body fat in-depth so there can be adequate targeted depression for obesity prevention, and adequate monitoring of obesity health impacts.

METHODS

Study design

The study was conducted from March to May 2023 at Al-Sader Teaching Hospital, Al-Najaf, Iraq, where 200 adult participants from both genders were evenly split (100M: 100F) and aged 18-60 years as per the set criteria, were recruited using a stratified sampling technique. However, the sample excluded children, pregnant women, and patients with a pacemaker due to medical contraindications with bioelectrical impedance analysis (BIA) (16).

Anthropometric Measurements

To measure the weight, the patients had to step on the calibrated electronic scales set to the nearest 0.01 kg cover, height was measured to the nearest 0.1 cm using a stadiometer and the participants had to stand upright while aligning both and the head with the vertical plane. Body mass index was calculated as weight (kg) divided by squared height (m^2) (3). Step 3 and 4 of the Global Aerometric Guidelines were properly followed. Other processes were followed in accordance with the WHO standards of anthropometric assessment (5).

Body Composition Assessment

Body composition was assessed using the InBody 370 bioelectrical impedance analyzer (InBody Co, Seoul, Korea). This device calculates body fat percentage (BF%), lean body mass, and body fat which every body part is wrapped in based on the conductivity of some body tissues (16,17). The criterion for diagnosing obesity was set at BF% > 28% for females and > 20% for males which is in agreement with the cut-off values applied in some studies (13,14).

Data Analysis

BMI cut-off points of 30 kg/m2 (obese) and 25 kg/m2 (overweight/obese) were evaluated for BF% in order to assess diagnostic accuracy. These values were determined for sensitivity, specificity, positive predictive (PPV) and negative predictive (NPV) values, and likelihood ratios. Stratified analyses by gender were conducted to determine the differences that may exist between males and females. All analyses were performed with SAS version 9.1.

RESULTS

The total number of subjects with records pertaining to patient demographics was 200 men and women who aged 32.7 ± 15.6 and 29.3 ± 8.7 years respectively. The average Body Mass Index (BMI) for men was 27.19 ± 9.58 kg/m² while it was 28.0 ± 9.95 kg/m² for women. The average body fat percentage (BF%) for men was 26.37 ± 11.52% while for women, it was 37.49 ± 10.38%. At a BMI ≥30 kg/m² 36% of females and 30% of males were classified as obese. However, using BF% criteria for obesity, 58% of women and 56% of men were classified as obese.

Table (1): Anthropometric measures for participants.

Age/years(n)	Weight (Kg)	Height (cm)	BMI (Kg/m^2)	BF%	Fat free mass	BMI Obese	BF% Obese
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Number (%)	Number (%)
Men (100)	80.3±30.4	171.1±6.5	27.1±9.5	26.3±11.5	56±12.8	30(30%)	56(56%)
18-40 (80)	79.6±32.4	171.7±6.2	26.7±10.1	24.6±11.4	56.7±13.6	22(27.5%)	38(47.5%)
41-60 (20)	83±20.8	168.8±7.4	29.1±6.9	33.4±9	53.4±8.8	8(40%)	18(90%)
Women (100)	70.3±24.6	158.7±4.6	28±9.9	37.4±10.3	41.7±8.2	36(36%)	58(58%)
18-40 (88)	67.3±24	159.1±4.6	26.6±9.5	36.1±10.2	40.8±8.1	26(29.5%)	46(52.3%)
41-60 (12)	92.4±18	156±4	37.9±7.1	47.1±4.2	48.1±5.9	10(83.3%)	12(100%)

Performance of BMI in diagnosing obesity

The percent body fat compared to BMI over 30 showed 100% specificity and 57.9% sensitivity. When the analysis was performed separately for men and women, both maintained the BMI over 30 fatness thresholds for perfect specificity; however, poor sensitivity (53.6% in men, 62.1% in women) persisted. The sensitivity and specificity for diagnosing overweight with BMI over 25 kg/m² was 84.2% and 95.3% respectively. When analyzed separately by gender, women with BMI over 25 kg/m² showed 100% specificity while men had 90.9% sensitivity, with both sexes demonstrating good weight fatness classification (82.1% women, 86.2% men). The classification of body fatness associated with the use of BMI is demonstrated in Table 2.

Table (2): Accuracy of body mass index to diagnose obesity using cut-off values ≥ 30 and ≥ 25 kg/m^2 according to gender.

Groups	Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)		LR +		LR -	
	BMI ≥ 25	BMI ≥ 30	BMI ≥ 25	BMI ≥ 30	BMI ≥ 25	BMI ≥ 30	BMI ≥ 25	BMI ≥ 30	BMI ≥ 25	BMI ≥ 30	BMI ≥ 25	BMI ≥ 30
Total	84.2	57.9	95.3	100	96	100	82	64.2	18.1	Inf	0.16	0.42
Men	82.1	53.6	90.9	100	92	100	80	62.9	9.03	Inf	0.19	0.46
Women	86.2	62.1	100	100	100	100	84	65.6	inf	Inf	0.13	0.37

DISCUSSION

This study on an Iraqi population shows that BMI has a low diagnostic accuracy to detect persons with increase in fat of the body, especially for those with 25-30 kg/m^2 body mass index. The correlation between BMI and BF% generally good, but unfortunately it fails to differentiate between fatty and non-fatty tissues. Also, the sensitivity of BMI ≥ 30 kg/m^2 to give correct diagnosis of adiposity is relatively low, losing nearly 50% of people with obese people diagnosed by body fat percent, whereas the specificity is good. Previous researches have also found generally excellent relationship between body mass index and body fat percent and significant differences at personal level. Researches examining the accuracy of BMI (18,19), found that BMI has low sensitivity but a good specificity to detect obesity. Studies on children found the same result. The correlation between body mass index and body fat percent in highest percentiles in teenagers is good while in lower percentiles is low (20,21).

From the results of this study, it is clear that the accuracy of BMI is limited in middle values of weight of the body particularly due to inability of BMI to differentiate between lean mass and body fat. In fact, the analyses of this study show that BMI correlated with lean mass like that with fat of the body. Indeed, in males BMI had good correlation with lean mass than with fat of the body. On the other hand, in females the action of BMI had better performance than males, which may be the cause that mortality in females with BMI defined overweight has been more consistently in previous studies (22,23). Considering the harmful effects of fat tissue on health, we'd expect a clear connection between body weight (adjusted for height) and health outcomes. However, most studies examining weight's impact on survival show a U or J-shaped curve, or a flat line for overweight BMI (25-27 kg/m2) followed by a rise in risk (7-9). The results showed people with normal or slightly elevated BMIs had varying combinations of fat and muscle, this explains the inconsistent link between BMI and health problems. In addition to that, BMI performed worst in the elderly, where most deaths in survival studies occur. This poor accuracy in older adults might also explain the unclear link between BMI and survival rates.

The issue with BMI is that it uses total body weight, which combines two factors with opposite health effects: fat tissue (bad) and muscle mass (good). Muscle mass is linked to better fitness, higher calorie burning, and better exercise capacity, all associated with better survival (24-26). For example, someone with a BMI of 25 could have good muscle mass and slightly high fat content, while another person with the same BMI might have low muscle mass and high fat. So, this highlighting BMI's limitations in predicting long-term health. The results of this study also suggest the obesity epidemic's true size might be much larger than BMI suggests (27). BMI showed a concerningly low ability to detect excess body fat, with about half of obese individuals (based on body fat measurements) being classified by BMI as overweight or normal. Real obesity prevalence could be significantly higher than BMI calculations. Additionally, adjusting BMI cutoffs for obesity doesn't fix this limitation. Lowering the cut-off to 25 kg/m2, for instance, would still misclassify 18% of men and 14% of women as obese. Misclassifying patients has significant consequences. Using BMI to identify obesity means we miss about 50% of people with excess body fat, who could benefit from interventions to reduce health risks (28,29). Conversely, BMI might label people with normal fat levels as overweight, causing unnecessary stress and potentially leading to pointless and expensive interventions. Additionally, such mislabeling can damage public trust in healthcare providers, especially for fit patients with clearly visible muscle mass. In spite of this study highlights the low performance of body mass index for diagnosing obesity, it's important to note that BMI isn't entirely useless. A BMI of 30 kg/m2 or higher has excellent accuracy for identifying obesity in both men and women[28]. This might explain why the risk of death from all causes and cardiovascular disease typically increases when BMI reaches 30 kg/m2 or higher. It suggests that BMI's subpar performance in detecting excess fat might be limited to the middle BMI ranges. BMI might still be a valuable tool in clinical practice for identifying people in the extremes of weight (those with a BMI of 30 kg/m2 or higher (likely having excess body fat) and those with a BMI below 18.5 kg/m2). While BMI and weight changes might suggest fat gain (except for muscle builders or those with fluid retention), they aren't perfect tools for spotting excess fat, especially in people with average BMIs. This is because BMI can't tell the difference between extra fat and healthy muscle.

CONCLUSION

This study illustrated that despite being one of the key parameters used in diagnosing obesity, Body Mass Index has limited accuracy in comparison to body fat percentage derived from bioelectrical impedance body fat analysis scales. A BMI of 30 kg/m² was considered the threshold. It had high specificities but low sensitivities which resulted in the underdiagnosis of people with excess fat. When the threshold was shifted to 25 kg/m², sensitivity was improved, although the specificity loss increased, particularly among the females. These results illustrate that the BMI metric, although fundamentally important, does not differentiate between muscle and fat tissue. Hence, the metric does not provide comprehensive estimates of obesity and its prevalence, and that changes fundamentally how clinicians and other health professionals approach the issue, especially engagement. This paper encourages the use of bioelectrical impedance alongside BMI in order to provide better clinical and research evaluations of obesity.

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Ethical Considerations

The study protocol was approved based on a detailed ethical methodology, in accordance with the ethical procedures established by the College of Medicine, Al-Qadisiyah University. The guidelines of the Declaration of Helsinki were adhered to at every stage of the study. Each subject was provided with a sufficient participant information sheet and signed a written informed consent form prior to participating in the study.

Conflicts of Interest

The authors have disclosed no conflicting financial or other interests.

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