Progress in Nutrition 2016; Vol. 18, N. 1: 39-46 © Mattioli 1885

Original Article

# Impedancemetry *vs*. anthropometry in the prediction of body adiposity and obesity diagnosis

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**Summary.** *Background and aim:* Many Bioelectrical impedance analysis (BIA)-based parameters require clinical evaluation. This study was performed to evaluate the relationships between some BIA-based parameters and anthropometric parameters for obesity diagnosis. *Methodology:* A total of 358 male subjects aged from 19-63 were enrolled in a cross sectional study. The anthropometric measures included weight, height, body mass index (BMI), waist circumference, hip circumference and waist hip ratio. InBody 720 was used to calculate the fat mass, fat mass index (FMI), percent body fat, visceral fat area (VFA), and other related measures. *Results:* Fat mass index had stronger positive correlation with BMI than percent body fat ($r$=0.9161 vs. $r$=0.7516, $P$<0.00001), and VFA was positively correlated with waist circumference ($r$=0.692, $P$<0.00001). Kappa analysis showed that BMI was highly related to FMI, especially when using BMI with Asian cutoff values (27.5 kg/m$^2$) ($k$=0.671 *vs.* $k$=0.560, $P$<0.00001). The ROC curve indicated that FMI was accurate in the diagnosis of obesity ($AUC$= 0.970). The FMI cutoff value with the best sensitivity and specificity (89% and 95%, respectively) was 9.20 kg/m$^2$. The VFA cut point of the best sensitivity and specificity (81% and 91%, respectively) was 129.45 cm$^2$. *Conclusion:* FMI is a better predictor of obesity than percent body fat and its cut off point is 9.20 kg/m$^2$. Furthermore, VFA is a good predictor of central obesity, and its cut off point is 129.45 cm$^2$

**Key words:** bioelectrical impedance analysis, InBody 720, fat mass index, body mass index, visceral fat area

## Introduction

Obesity is highly prevalent metabolic disorder that reaches the pandemic nature. It affects approximately 300 million people all over the world and is accompanied by increased mortality and reduced life expectancy (1). Obesity is caused by an excess of body fat, so measuring body fat is essential for the diagnosis of obesity and is associated with the assessment of its comorbidities (2).

The traditional methods of body fat measurement usually range from simple measures, such as waist circumference (WC), waist-to-hip ratio (WHR), body mass index (BMI) and subcutaneous skinfold thickness, to more complex methods, such as, bioimpedance assessment and dual-energy x-ray absorptiometry (DXA) (3). BMI is the most widely used diagnostic tool to diagnose and assess the degree of obesity within a population due to its reliability and clinical validity as a method (4). Furthermore, many studies have shown that as BMI increases, the risk of metabolic derangement-related diseases increases, and BMI may be used as an indicator for the prediction of these diseases (5). However, many studies observed a low sensitivity for BMI to diagnose obesity in general (6), while others demonstrated that BMI was the most inaccurate method for the diagnosis of obesity among intermediate ranges of BMI, as it cannot discriminate between body fat and lean mass (7,8). In addition, ethnicity, gender and age all affect the accuracy of BMI in the detection of body adiposity (9).

Bioelectrical impedance analysis (BIA) is a relatively simple, quick and noninvasive method of body composition assessment. It is reliable, and easy to perform and is widely used in clinical practice. According to ESPEN guidelines, suggest that BIA works well in healthy subjects as well as in patients with a stable balance of water and electrolytes and with a validated BIA equation that is appropriate with regard to age, sex and race (10). Fat-free mass (FFM), percent body fat (PBF), body cell mass (BCM), total body water (TBW), extracellular water (ECW), intracellular water (ICW), visceral fate area (VFA) and other parameters of body composition can be estimated by a BIA device using many appropriate population, age or pathology-specific BIA equations and established procedures (11). Furthermore, it was found that the PBF calculated by BIA was significantly close to values obtained from DXA and hydrostatic weighing (HW); thus, there is good agreement between BIA and DXA (12). The clinical value of many BIA-based parameters, such as the fat mass index (FMI) and visceral fat area (VFA), and their correlation with anthropometric measures such as BMI, WC and WHR, is underinvestigated. We undertook a study to assess the relationships between BIA-based parameters (FMI & VFA) and traditionally used anthropometric parameters (BMI & WHR) in a male sample visiting the weight reduction clinic at King Saud University, Riyadh, KSA.

## Methods

*Study population*

All subjects were visitors or cases at the weight reduction clinic in College of Applied Medical Sciences (CAMS), male sector, King Saud University. A total of 358 male subjects aged 19-63 years were enrolled in the study. Subjects with edema, cancer, severe disability, or severe psychiatric disturbance were excluded. Informed consent was obtained from each participant before the study. The CAMS research ethics committee approved the study protocol.

*Demographic variables*

Socio-economic status questionnaires were completed taking into consideration variables such as ethnicity (Saudi or non-Saudi), marital status and annual income.

*Anthropometric measures*

Anthropometric measures including weight, height, BMI, waist circumference (WC), hip circumference (HC) and mid-arm circumference (MAC) were measured by a clinician or a trained assistant. Body weight and height was measured using a Seca digital scale with a nonstretchable stadiometer (Seca Co, Germany). BMI was calculated as the body weight in kilogram divided by the square of height in meters. The cut off point for BMI in this study was based on the WHO international criteria for all populations (>30 kg/m$^2$) (13) and the WHO criteria for Asian populations with suggested public health action (>27.5 kg/m$^2$) (14). WC was determined by measuring waist diameter at the midpoint between the iliac crest and lower border of the tenth rib. An average of two measurements was considered as WC. HC was assessed on lateral position by measuring the circumference at the most prominent point, and an average of two measurements was used to determine HC. Waist-hip ratio (WHR) was calculated by dividing WC by HC. The cut off values for WC and WHR in this study were 90 cm and 0.9, respectively, based on Dobbelsteeyn et al (15). Due to local traditions and culture, WC, HC and MAC were measured with the subjects wearing lightweight clothes, but weight and height were measured when the subjects were not wearing shoes.

*Bioelectrical impedance analysis*

BIA analysis was assessed by InBody 720 (InBody, Biospace, Korea). The subjects were asked to first wipe the soles of the feet and palms of the hands with an electrolyte tissue and then to stand over the electrodes of the machine. The results were ready in 1-2 min. The parameters recorded included body weight, BMI (height was manually inputted), degree of obesity, protein mass, mineral mass, total body water, intracellular and extracellular water, skeletal muscle mass, fat free mass (FFM), fat mass (FM), percent body fat (BPF), visceral fat area (VFA) and fitness scoring based on the target values for ideal body fitness. InBody 720 emits many frequencies of electric current (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1 MHz). This multifrequency technology especially at 5 kHz, 50 kHz and 250 kHz was used to more accurately measure the resistance, reactance, and components of body impedance used to accurately calculate body water, FM, FFM, and another related measures. PBF cut off points used in this study were defined according to Okorodudu et al. (4, 16). The parameters of clinical common use, such as FM, PBF and VFA, will be analyzed in this study.

*Statistical analysis*

Statistical analysis was performed using SPSS for Windows (version 19.0; SPSS Inc., Chicago, IL, USA). The data were summarized as the means, standard deviations (SD) and ranges. Mann-Whitney test was used to differentiate between ethnic groups. Pearson's correlation coefficient was used to demonstrate the relationship between age, BMI, WHR, BF%, FMI and VFA. $P \leq 0.05$ was considered statistically significant. Kappa analysis was performed to study the agreement between BMI and FMI in addition to WHR and VFA, with a 95% confidence interval (95% CI). An ROC curve was used to detect obesity and identify new cut off points with a higher sensitivity (true positive rate) and specificity (true negative rate) of FMI and VFA. Positive predictive values (PPVs) and negative predictive values (NPVs) were also calculated and compared for proposed and standard FMI cutoffs.

## Results

All descriptive characteristics and ethnic comparison of the entire study population are shown in Table 1 in the form of the means±SD and ranges of measures. There were no significance ethnic differences between Saudi and non-Saudi males using the Mann Whitney test.

The Pearson correlation showed that FMI had a strong positive correlation with BMI ($r=0.9161$, $r^2=0.8392$, $P<0.00001$, Figure 1a). The correlation was strong between PBF and BMI, but it was significantly less than that with FMI ($r=0.7516$, $r^2=0.5649$, $P<0.00001$, Figure 1b). However, there was a moderate positive correlation between VFA and WC ($r=0.692$, $r^2=0.4789$, $P<0.00001$, Figure 2a) while the correlation between VFA and WHR was weak ($r=0.1648$, $r^2=0.0272$, $P=0.058012$, Figure. 2b).

Kappa analysis showed that BMI was highly related with FMI ($k=0.560$, $P<0.00001$) and the kappa value was higher when using BMI with Asian

**Table 1.** Descriptive variables of study population

| Variables | All cases (n=358) | | Saudi (75.24%) | | Non Saudi (24.76) | |
|---|---|---|---|---|---|---|
| | Mean±SD | Range | Mean±SD | Range | Mean±SD | Range |
| Age | 31.18±11.27 | 19.00-63.00 | 27.63±9.28 | 19.00-62.00 | 42.40±9.50 | 26.00-63.00 |
| Weight | 101.55±24.18 | 43.00-211.00 | 106.02±23.41 | 68.00-211.50 | 100.79±18.11 | 59.00-144.90 |
| Height | 172.00±6.94 | 157.00-187.00 | 173.15±6.93 | 157.00-187.00 | 171.41±7.05 | 160.00-187.00 |
| BMI | 34.02±7.17 | 16.59-70.67 | 35.24±6.84 | 24.97-70.67 | 34.23±5.52 | 22.76-47.31 |
| WC | 107.43±13.82 | 69.00-145.00 | 107.41±14.29 | 69.00-145.00 | 108.20±10.87 | 94.00-130.00 |
| HC | 114.23±13.14 | 86.00-160.00 | 114.77±13.10 | 86.00-16.00 | 112.17±12.69 | 88.00-143.00 |
| WHR | 0.94±0.07 | 0.58-1.18 | 0.93±0.74 | 0.58-1.18 | 0.96±0.06 | 0.81-1.12 |
| PBF | 36.30±9.28 | 9.70-54.20 | 38.22±7.98 | 10.80-54.20 | 36.33±8.03 | 14.60-51.80 |
| FMI | 12.84±5.53 | 1.62-38.29 | 13.82±537 | 5.04-38.29 | 12.62±4.59 | 4.90-23.73 |
| VFA | 167.61±64.79 | 54.10-549.30 | 163.76±67.21 | 54.10-549.30 | 174.19±58.35 | 65.00-314.00 |
| FFMI | 21.00±3.11 | 14.20-44.24 | 21.20±3.21 | 14.34-44.24 | 21.49±2.54 | 17.40-28.67 |

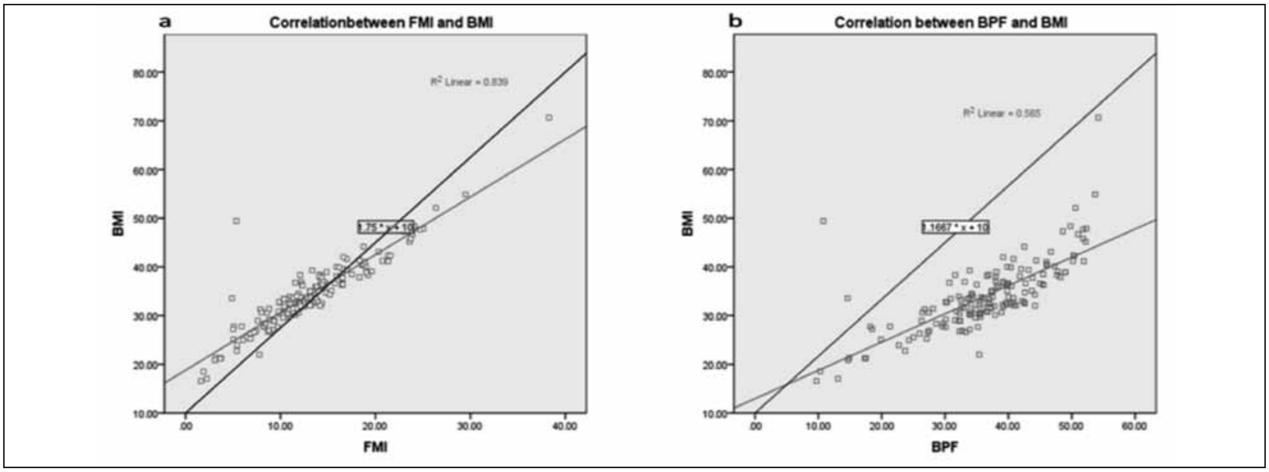


**Figure 1.** Correlation between FMI & BMI (a) and BPF & BMI (b).

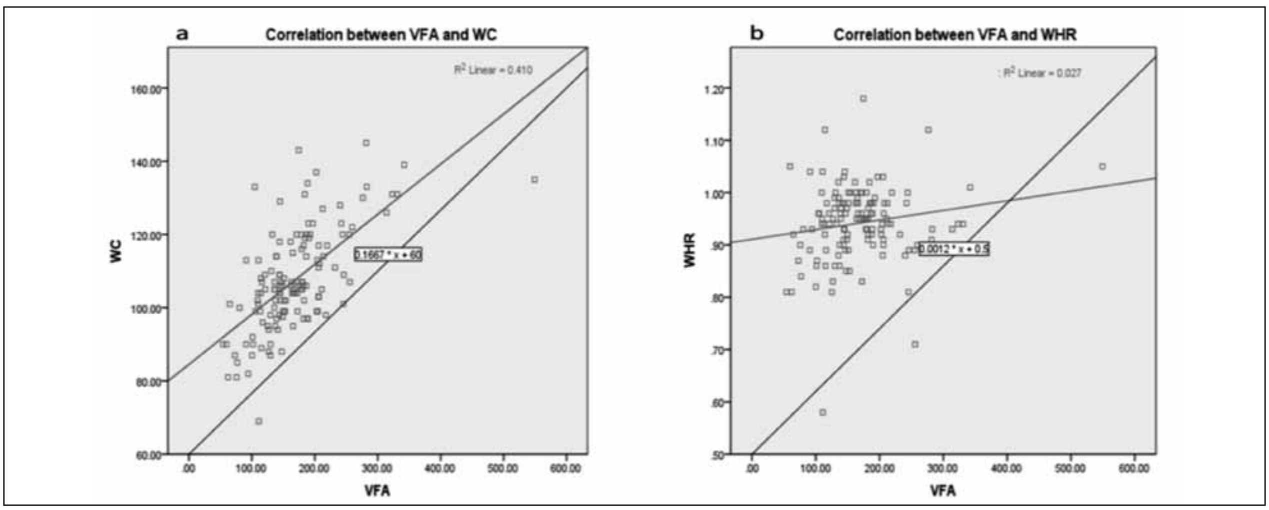


**Figure 2.** Correlation between VFA & WC (a) and VFA & WHR (b).

cutoff values (27.5 kg/m$^2$) (k=0.671 vs. k=0.560, P<0.00001). On the other hand, kappa analysis demonstrated that the agreement between BMI and PBF was lower than that between BMI and FMI (k=0.474 vs. k=0.560 when using a BMI cut off value at 30 kg/m$^2$ and k=0.563 vs. k=0.671 when using a BMI cutoff value at 27.5 kg/m$^2$, respectively, P<0.00001).

By using WHO criteria for Asian populations (BMI≥27.5), the area under the ROC curve was 0.970 (Fig. 3a) indicating that FMI is accurate in the diagnosis of obesity. The FMI cut off value of the best sensitivity and specificity (89% and 95 %, respectively) was 9.20 kg/m2. The condition is slightly different when using the WHO International Criteria (BMI ≥30), i.e., area under the curve was 0.969 (Figure 3b), and the FMI cut off value with the best sensitivity and specificity (93% and 92%, respectively) was 9.54 kg/m$^2$.

Figure 4a shows the ROC curve of VFA based on the WC reference for males (15); the area under the curve was 0.892, indicating that the accuracy of VFA in the diagnosis of central obesity is high. The VFA cut off values with the best sensitivity and specificity (81% and 91%, respectively) was 129.45 cm$^2$. Using WHR criteria, the area under the curve was 0.662 (Figure 4b), and the best cut off point, with 57% sensitivity and 71% specificity, was 152.15 cm$^2$.

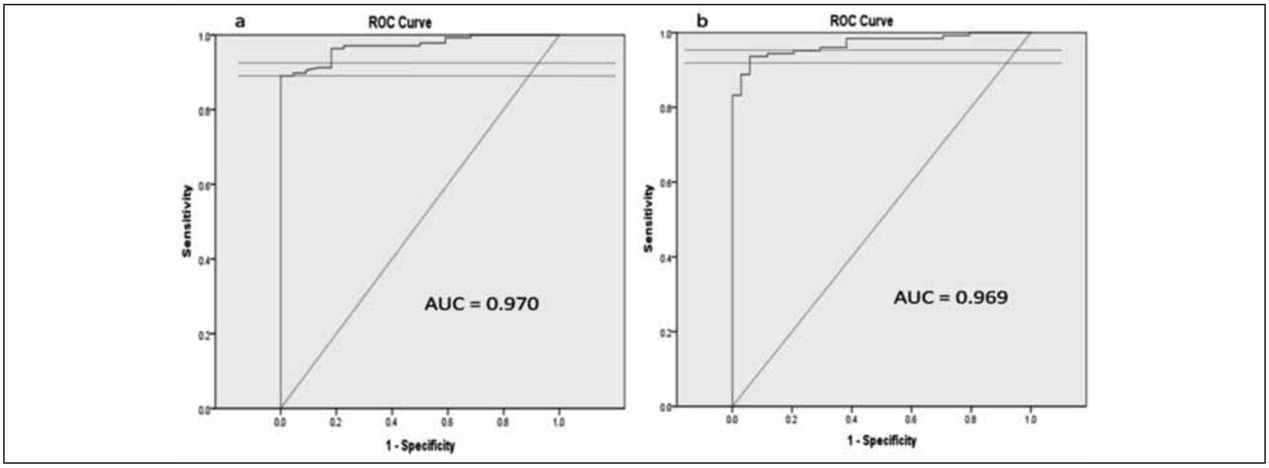


**Figure 3.** ROC curve showing sensitivity and specificity of FMI at different cutoff points in addition to area under the curve (AUC); a) using BMI criteria for Asian i.e. ≥27.5, b) using BMI criteria for international population i.e. ≥ 30 Kg/m2.

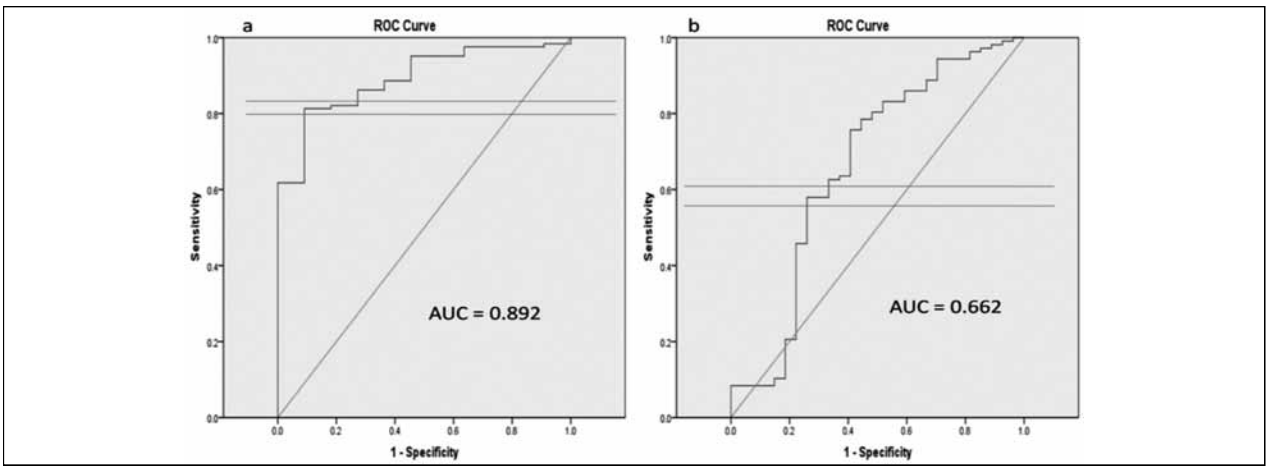


**Figure 4.** ROC curve showing sensitivity and specificity of VFA at different cutoff points in addition to area under the curve (AUC); a) using WC reference for male i.e. ≥90 cm, b) using WHR criteria for males i.e. ≥ 0.9 .

## Discussion

BIA devices are commonly used in obesity clinics and in many wards in clinical practices. BIA-based parameters are frequently used, and some are valuable in the assessment of body composition especially in fields studying obesity and metabolism. In present clinical practices, BMI is usually considered a surrogate marker of excess adiposity in terms of overweight and obesity. People with the same BMI or the same PBF may have very different body compositions, which may result in exposure to different metabolic conditions; therefore, it is better to measure and express body composition as FMI and FFMI rather than either BMI or PBF (17). Thus, the ideal alternative is to use actual measures of body fat rather than BMI.

The present study suggests the use of FMI as a good alternative with a higher sensitivity and specificity for the diagnosis of obesity and its stages. FMI shows a strong positive correlation with BMI. Mathematically, BMI = FMI + FFMI, and because excess body adiposity is the main pathology in all obesity phenotypes even in sarcopenic obesity (18), kappa analysis revealed that the agreement between BMI and FMI is higher than that with PBF; therefore, it is logical to use FMI instead of BMI as a diagnostic index for obesity.

These findings are in line with Schutz et al's (19) study in which they created reference percentiles for

FFMI and FMI and stated that these percentiles could be of practical value, especially for the clinical evaluation of sarcopenic obesity, complementing the classical concept of BMI in a more qualitative manner. Furthermore, Kang et al (20) found that FMI and PBF were useful parameters to study the relationship between osteoporosis and obesity at the same time. However, Ribeiro et al (21) preferred the use of BMI, WC and waist-to-height ratio as diagnostic tests to identify excess body fat in children from seven to ten years of age; this discrepancy may be due to different ages within the study population. In addition, Habib (22) used PBF and BMI as a reference for the assessment of obesity and its prevalence.

VFA is a beneficial marker of visceral adipose tissue that is usually incriminated in the pathogenesis of many obesity-related comorbidities, especially in men (23).Its measurement via BIA is more reliable and easier than other complex indices that need lipid profile testing such as the visceral adiposity index (VAI) (24) and lipid accumulation product (25) or those obtained by different equations based on anthropometric measures, such as the body adiposity index (26) and conicity index (27). Furthermore, Mohammadreza et al (28) concluded that using complex indices such as VAI instead of simple anthropometric measures might lead to the loss of a significant amount of information necessary for predicting incident cardiovascular death. Generally, the higher the WC value, the more likely metabolic risk will accumulate, as the prevalence of metabolic risk increases linearly and significantly in relation to WC levels (29). In addition, WC is a reliable measure of total abdominal fat, but its association with intraperitoneal fat depends on the ratio between intraperitoneal fat and abdominal subcutaneous fat that varies by gender and ethnicity (30). This study showed a moderate positive correlation between VFA and WC that was not the case with WHR. This was in line with Mateo-Gallego et al (31), who found that age plays an important role in the association between WC and FVA measured by BIA with a high correlation existing in all age ranges.

The next finding in this study was the finding of a new cutoff value for FMI and VFA in the studied sample. The ROC curve analysis showed that the cut off value for FMI with 89% sensitivity and 95% specificity was 9.20 kg/m$^2$ based on obesity defined by BMI as 27.5 kg/m$^2$. The cut off value for FMI was previously defined in an Indian samples to be 6.6 kg/m$^2$ in men predicted to have 25% body fat. The authors of this study calculated fat mass using skin-fold measurements (32). Another FMI cutoff point was defined by Schutz et al (19) who calculated FM by BIA and found that the 95th percentile of the FMI was 7.0 kg/m$^2$ in Caucasian young adult males and progressively rose with age (by 2 units). In addition, this 7 kg/m$^2$ value was reported by Liu et al (33) and was considered an independent screening factor for metabolic syndrome in Korean men.

The optimal cut off point with the best sensitivity and specificity (81% and 91%, respectively) for VFA in our study population was 129.45 cm$^2$. This value seems higher than other cut off values defined by other investigators using different methods of visceral fat area detection in various ethnic groups. Another Egyptian study used ultrasound for measuring VFA and WC as a standard for the classification of central obesity; the cut off value for visceral fat was found to be 6.5 cm for men (34). A Korean study using computed tomography to measure VFA found the cutoff value for VFA to be 92.6 cm$^2$ in men (35). Oqawa et al (36) concluded that BIA determined by InBody 720 was a useful and convenient substitute for computed tomography when measuring VFA. Lee et al (37), who compared InBody 720 results with CT and DXA in premenopausal adult women (the BIA-VAT was 120.2 cm$^2$ and CT-VAT was 111.6 cm$^2$), disagreed with these results and concluded that BIA is not appropriate for the evaluation of abdominal visceral obesity in premenopausal women.

Finally, this study has several limitations. First, the absence of female subjects was due to limited access to female cases in Saudi Arabia. The second limitation is the comparison of BIA-based results with CT- or DXA-based results. The third limitation was, that samples from different regions of SA.

Despite these limitations, our study can conclude that FMI and VFA seem to be better indicators in screening for obesity than BMI, WHR and PBF in men living in Riyadh, SA. Future research using larger sample sizes from many regions of the kingdom and including both male and female subjects is needed to validate these results.

## Acknowledgment

The authors extend their appreciation to the Deanship of Scientific Research at King Saudi University, KSA for funding the work through the research group project no RGP-193).

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