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A pilot study comparing bioelectrical impedance analysis and body mass index in determining obesity among staff of a Ghanaian University

Frank Ekow Atta Hayford  
Department of Nutrition and Dietetics,  
School of Biomedical and Allied Health Sciences, College of Health Sciences, University of Ghana, Accra, Ghana and Centre for Excellence in Nutrition, North-West University, Potchefstroom Campus, Potchefstroom, South Africa

Collins Afriyie Appiah  
Department of Biochemistry and Biotechnology (Human Nutrition and Dietetics Unit), Faculty of Biosciences, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Taofik Al Hassan  
Department of Nutrition and Dietetics, School of Biomedical and Allied Health Sciences, College of Health Sciences, University of Ghana, Accra, Ghana

Odeafo Asamoah-Boakye  
Department of Biochemistry and Biotechnology (Human Nutrition and Dietetics Unit), Faculty of Biosciences, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and

Matilda Asante  
Department of Nutrition and Dietetics, School of Biomedical and Allied Health Sciences, College of Health Sciences, University of Ghana, Accra, Ghana

Abstract

Purpose – In Ghana, the body mass index (BMI) is widely used in clinical practice in assessing weight status, but it is limited as a measure of adiposity. The purpose of this study was to compare bioelectrical impedance analysis (BIA) and body mass index (BMI) methods in determining obesity among some Ghanaians.

Design/methodology/approach – This was a cross-sectional survey involving 134 participants whose BMI were determined. Percentage body fat mass (%BF) and percentage visceral fat (%VF) were obtained by BIA using a hand-to-hand Omron body composition monitor with a weighing scale.

Findings – Based on the WHO BMI criteria, 6.0 per cent of the participants were obese. However, according to BIA 18.7 and 20.9 per cent of the participants were obese according to % BF and %VF, respectively. The BMI and %BF showed higher prevalence of obesity among female participants (8.2 and 34.4 per cent, respectively) than male participants (4.1 and 5.5 per cent, respectively), whereas for %VF, obesity was higher among male participants than female participants (26.0 per cent, 14.8 per cent). There was significant positive correlation between BMI and % BF ($r = 0.604, p = 0.001$); and between BMI and % VF ($r = 0.555, p = 0.001$).
Research limitations/implications – There are discrepancies in the prevalence of obesity in the study population as measured by BMI and BIA methods. This suggests that the BMI and BIA may not be reliable tools for assessing obesity in this population. Further studies are needed to determine the cut-offs for BMI and BIA that are associated with metabolic risk in the population. The small sample size limits the generalizability of findings of this study.

Originality/value – Body composition tends to vary by ethnicity and race; hence, it is essential to determine the appropriate tool for assessing adiposity in African populations for prompt and targeted interventions.

Keywords Obesity, Body mass index, Bioelectrical impedance analysis, Central obesity, Total body fat, Visceral fat

Paper type Research paper

Introduction
Globally, the prevalence of obesity is increasing at an alarming rate. In the developed world, the prevalence is on the ascendency in both men and women (Amugsi et al., 2017). Selthofer-Relatic et al. (2012) reported that at least 2.8 million people die each year as a result of being overweight or obese. The report also indicated that an estimated 35.8 million global disability adjusted life years were caused by overweight/obesity. Excessive body fat is among the primary risk factors for insulin resistance, hypertension and dyslipidaemia which may increase the risk of cardiovascular diseases and type II diabetes (Stranska et al., 2011). Moreover, obesity has been associated with an increased risk of cardiovascular diseases and all-cause mortality (Koolhaas et al., 2017; Barroso et al., 2017).

Indices of relative weight gain such as the body mass index (BMI) are commonly used to determine obesity. Obesity could result from generalised or localised body fat distribution. This limits the accuracy of the BMI as a tool for assessing obesity since it does not take into account individual differences such as body fat distribution and bone mass (Liu et al., 2011; Agarwal et al., 2010). Body composition can be measured by highly sophisticated and accurate methods like densitometry, plethysmography, nuclear magnetic resonance and dual-energy x-ray absorptiometry. However, these methods are complex, time-consuming, expensive and require a great deal of training to operate, and for these reasons, their use in clinical practice and large epidemiological studies is limited (Bi et al., 2018; Ramirez-Velez et al., 2017; Pereira et al., 2015). The BMI is a widely used anthropometric measurement tool in clinical settings to characterise obesity in individuals. The BMI, as measured by weight to height ratio, is a weight excess index not specific to body fat composition (Wang et al., 2010). This method is particularly limited in athletes and other individuals with high lean body mass as their high lean mass could raise the weight to height ratio resulting in false classification of their weight status as overweight/obese. This limits the applicability of the BMI across different populations (Rahman and Berenson, 2010; Gurunathan and Myles, 2016; Mahadevan and Ali, 2016). These limitations have prompted the use of bioelectrical impedance analysis (BIA) for assessing adiposity. BIA has been shown to produce a close estimate of fat mass in a wide range of body compositions (Huang et al., 2015; Raeder et al., 2017) and also has many advantages compared with other methods because it is inexpensive, simple, fast, safe and easy to use, as well as requiring no special hands-on training (Ramirez-Velez et al., 2017; Raeder et al., 2017). Instead of using proxies for assessing obesity as done by the BMI, BIA measures the proportion of body fat (Huang et al., 2015). It is able to distinguish body fat from fat-free mass. Additionally, body fat proportion (%BF) measured by BIA has been reported to be more effective in detecting individuals with risk of cardio-metabolic disease (Gomez-Ambrosi et al., 2011; Shea et al., 2012; Yamashita et al., 2012; Dee et al., 2012). There are less data comparing the BMI and BIA in determination of adiposity among African populations. The availability of reliable tools to
accurately identify obesity in the Ghanaian population is critical in efforts towards combating the surge in obesity and its associated morbidities. This pilot study sought to compare BMI and BIA methods in determining obesity among university staff members in Ghana.

Methods

Study design

This was a cross-sectional study. A total of 134 healthy staff members (≥18 years) from the College of Medicine and Health Sciences, University for Development Studies, Wa, Ghana were recruited into the study. Participants were conveniently sampled from the staff members of the departments under the College.

Study population and sampling

This study involved University staff members from the College of Medicine and Health Sciences, University for Development Studies, Wa, Ghana. The population included academic staff members of the Department of Medicine, Department of General Nursing, Department of Nursing Practitioners, Department of Nursing Anesthetics, Department of Nutrition, Department of Health Education and the Department of Laboratory Sciences. In total, 134 staff members within the college were conveniently sampled to participate in the study.

Eligibility

The study included healthy adult staff members of the College of Medicine and Health Sciences who were ≥18 years. Staff members with known chronic disease such as hypertensives on diuretics and people with heart implants were excluded. Pregnant and lactating women were also excluded.

Sample size

The Cochrane’s formula for cross-sectional study was used to determine the minimum sample size for the study:

\[ N = Z^2 \left( \frac{P}{1 - P} \right) / \delta^2. \]

“N” is the sample size, Z is the standard score for the confidence level, P is the population proportion (prevalence) and “δ” is the level of statistical significance. The prevalence of adult obesity in the northern region of Ghana (1.5 per cent) was used. At 95 per cent confidence level, Z score is 1.96.

Ethical approval

Approval was obtained from the Ethics and Protocol Review Committee of the School of Allied Health Sciences, University of Ghana (SAHS-ET/10274339/AA/8A/2012-2013). A written informed consent to participate was obtained from the participants before recruiting into the study.

Data collection

Participants were made to complete a socio-demographic questionnaire. Their heights were measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, UK). Weights of participants were measured to the nearest 0.1 kg using the Omron body composition monitor. The BMI was determined using the relation; weight (in kilogram) divided by height (in meters) squared. The WHO (2004) BMI criteria for adults were employed to categorise
participants into underweight (<18.5 kg/m²), normal weight (18.5-24.5 kg/m²), overweight (25-29.9 kg/m²) and obese (≥30 kg/m²). Percentage body fat (%BF) and percentage visceral fat (%VF) were obtained using BIA method using hand-to-hand Omron BF-500 (Omron, Japan). Generalised obesity was defined as body fat percentage >24 per cent in males and >35 per cent in females, while central obesity was defined as visceral fat >9 per cent (Gallagher et al., 2000). All anthropometric data were taken before participants took their first meal in the morning.

Validation of bioelectrical impedance analysis
Validation of the body composition analyser was done by comparing %BF and %VF measures from two different Omron body composition monitors. Reliability of each device was determined after each measurement was repeated three consecutive times. The values were, on average, similar for both analysers.

Statistical analysis
Statistical analysis was performed using statistical analysis software SPSS version 20. Descriptive statistics was used to determine frequencies and percentages of categorical variable. Pearson correlation test was performed for analysis of statistical relationship between the two anthropometric methods. A $p < 0.05$ was considered statistically significant.

Results
Sociodemographic characteristics of participants
A total of 134 participants were enrolled in the study with majority of participant between 29 and 38 years. The female participants were 61 (45.5 per cent) and male participants were 73 (54.5 per cent) (Table I).

Body mass index, percentage body fat and percentage visceral fat distribution by gender
The result showed 6.0 per cent of the participants were obese using BMI. Also, more female participants were overweight (18.0 per cent) and obese (5 per cent) than male participants (10.0 and 3.0 per cent), respectively.

Based on %BF, 18.7 per cent of the participants were obese and 20.9 per cent were obese according to %VF. Based on %BF, more female participants (34.4 per cent) were obese than male participants (5.5 per cent). The male participants (26.0 per cent) had higher central adiposity than female participants (14.8 per cent) (Table II).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>73</td>
<td>54.5</td>
</tr>
<tr>
<td>Female</td>
<td>61</td>
<td>45.5</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-28</td>
<td>37</td>
<td>27.6</td>
</tr>
<tr>
<td>29-38</td>
<td>49</td>
<td>36.6</td>
</tr>
<tr>
<td>39-48</td>
<td>22</td>
<td>16.4</td>
</tr>
<tr>
<td>59-68</td>
<td>20</td>
<td>14.9</td>
</tr>
<tr>
<td>≥69</td>
<td>6</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Table I. Sociodemographic characteristics of participants
A Pearson correlation analysis was performed to determine the relationship between the BMI and BIA as anthropometric tools to predict obesity. BMI and %BF had a significant positive correlation ($r = 0.604$, $p = 0.001$). BMI and %VF also had a significant positive correlation ($r = 0.555$, $p = 0.001$) (Table III).

### Table II.
#### Distribution of obesity prevalent using BMI and BIA by gender

<table>
<thead>
<tr>
<th>Anthropometric parameter</th>
<th>Male $n$ (%)</th>
<th>Female $n$ (%)</th>
<th>Total $n$ (%)</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI category</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.035</td>
</tr>
<tr>
<td>Normal</td>
<td>60 (82.2)</td>
<td>38 (62.3)</td>
<td>98 (73.1)</td>
<td></td>
</tr>
<tr>
<td>Overweight</td>
<td>10 (13.7)</td>
<td>18 (29.5)</td>
<td>28 (20.9)</td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>3 (4.1)</td>
<td>5 (8.2)</td>
<td>8 (6.0)</td>
<td></td>
</tr>
<tr>
<td><strong>BIA</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Normal</td>
<td>69 (94.5)</td>
<td>40 (65.6)</td>
<td>109 (81.3)</td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>4 (5.5)</td>
<td>21 (34.4)</td>
<td>25 (18.7)</td>
<td></td>
</tr>
<tr>
<td><strong>%Body fat category</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.387</td>
</tr>
<tr>
<td>Normal</td>
<td>54 (74.0)</td>
<td>52 (85.2)</td>
<td>106 (79.1)</td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>19 (26.0)</td>
<td>9 (14.8)</td>
<td>28 (20.9)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** $n$ = Frequency; % = Percentage; BMI = Body mass index; %BF = Percentage body fat; %VF = Percentage visceral fat; BIA = Body composition analyser; $p$-value is significant at $p < 0.05$

### Relationship between body mass index, percentage body fat and percentage visceral fat
A Pearson correlation analysis was performed to determine the relationship between the BMI and BIA as anthropometric tools to predict obesity. BMI and %BF had a significant positive correlation ($r = 0.604$, $p = 0.001$). BMI and %VF also had a significant positive correlation ($r = 0.555$, $p = 0.001$) (Table III).

### Discussion

Obesity has been described as an increase in the percentage of the body’s adipose tissue above acceptable range (Graf, 2011). The BMI is routinely used in clinical practice and population surveys to assess obesity mainly due to its simplicity and cost-effectiveness regardless of its limitations. An individual with a high lean body mass could have a BMI of >30 kg/m² but not necessarily be obese, as the increase in weight above normal is not from excess body fat. The term “obesity” specifically refers to excessive adiposity (WHO, 2004).

Several studies have demonstrated that the relationship between BMI and %BF differs among different ethnic groups hence, the need for reliable ethnicity-specific cut-off points to accurately detect the prevalence of obesity for effective public health intervention programmes and policies (Eyre et al., 2017; Ranasinghe et al., 2013). As most studies comparing BMI and body composition analysis were largely done among non-African populations, findings of this study provide insight in African populations.

This study found differences in the proportion of participants classified as obese according to BMI and BIA (%BF and %VF). The prevalence of obesity as detected by BIA (%BF) was found to be about threefold higher than BMI, implying that the participants have higher proportions of adipose tissue for a given BMI. This suggests that an individual with a

### Table III.
#### Relationship between BMI, %BF and %VF

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$R$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^\dagger$BMI and %BF</td>
<td>0.604</td>
<td>0.001</td>
</tr>
<tr>
<td>$^\dagger$BMI and %VF</td>
<td>0.555</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Notes:** $^\dagger$Pearson correlation analysis was done; $R$-Pearson correlation co-efficient; $p$-value is significant at $p < 0.05$
normal BMI could have high adipose tissue composition and thus be incorrectly classified as being of normal weight by BMI. This is consistent with studies in China (Wang et al., 2010), Turkey (Bozkirli et al., 2007) and India (Bhat et al., 2005) where some respondents with lower and normal BMIs were found to have higher percentages of adipose tissue. All these verified discrepancies in different populations urged Bergman et al. (2011) and Silva et al. (2016) to advocate for the use of the BIA method of assessing adiposity instead of the BMI. Based on gender, BMI and %BF showed higher prevalence of obesity among female participants than male participants, whereas for %VF obesity was higher among male participants than female. This implies that using only one anthropometric tool to assess the prevalence of obesity in the population may not be appropriate as this could result in inaccurate estimation of the prevalence rate. As such, obesity might not be detected for timely intervention. Combining %VF and %BF could quantitatively diagnose those at higher risk of chronic diseases, since both tools determine total fat mass and central obesity. Central adiposity has been associated with cardiovascular disease and diabetes (St-Onge and Gallagher, 2010). Men tend to be more predisposed to central obesity than women who tend to dispose more fat below the abdomen.

Findings of this study show that the prevalence of obesity using the %BF was higher among the female participants than male participants. This can be due to the fact that women tend to develop more body fat during the reproductive process, such as in the breast, gluteo-femoral region and ovaries, than men (Lee and Fried, 2017; Shapira, 2013).

The correlation between BMI, %BF and %VF in this study implies that increasing BMI could lead to increase in %BF and %VF among the participants and vice-versa. This was consistent with studies by Lopez et al. (2012) and Ranasinghe et al. (2013) which found strong positive correlation between BMI and %body fat.

In summary, in this cross-sectional pilot study, there were discrepancies in the prevalence of obesity among the population using the BMI and BIA. Although, BMI had significant positive correlation with %BF and %VF, prevalence of obesity between these anthropometric tools were different among the study population. This suggests that the use of BMI in determining obesity in Ghanaian population could potentially underestimate or overestimate obesity in the population, therefore efforts to accurately identify obesity in the population would help in prompt and targeted interventions.

Limitations
A major limitation of this study is the limited sample size of the cross-sectional design, which limits the generalizability of the study findings to the larger Ghanaian populace. A larger study is needed to determine the cut-offs for BMI and BIA in the population. Nonetheless, this study provides insights for larger research on the accuracy and validity of BMI and BIA methods of assessing obesity in the Ghanaian population.

Conclusion
Findings of this study suggest that the BMI is not a sensitive tool for determining obesity among the study population. BIA could be a better tool for assessing obesity in this population. Body composition tends to vary by ethnicity and race; hence, further large-scale studies are needed to determine the appropriate tool for assessing adiposity in the Ghanaian population for prompt and targeted interventions.
References


Further reading


Corresponding author

Frank Ekow Atta Hayford can be contacted at: feahayford220580@gmail.com

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