Relationship between Bioelectrical Impedance Analysis and Body Mass Index in Adolescent Urban Nigerians

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Abstract

Background: Body mass index is often used to assess adiposity but it does not differentiate between fat and non-fat components of body mass. However, body fat composition may be assessed using bioelectrical impedance analysis.

Objective: The study aimed to relate body mass index to fat in the assessment of overweight and obesity among adolescent Nigerians.

Methods: Adolescent pupils aged 10 years to 18 years from randomly selected secondary schools in Lagos, Nigeria were studied. Body mass index was calculated while percentage body fat was measured using Tanita body® fat scale model BF 681. Overweight and obesity were defined using age and sex specific criteria for body mass index and for body fat.

Results: There were 753 pupils {377 (50.1%) males and 376 (49.9%) females}. The overall mean body mass index for males and females were 18.1±2.72 and 18.9±3.41 (p < 0.05) respectively. The corresponding figures for body fat were 9.5±4.48 and 18.9±7.51 (p<0.05) respectively. About three quarters (76.2%) of the females who had body mass index in the overweight/obesity range had high body fat in comparison to 44.4% of males (p < 0.05).

Conclusion: Body mass index is more related to body fat in adolescent females than in their male counterparts. WAJM 2011; 30(2): 99–103.

Keywords: Obesity, overweight, body fat, body mass index, bioelectrical impedance.
INTRODUCTION

Tools available for the assessment of body fat composition and hence adiposity may be broadly classified into two - those for institution based research work and the anthropometric methods. The institution based research work methods include underwater weighing; and dual-energy x-ray absorptiometry.\(^1\) The size, cost and complexity of the equipment limit their use in clinical practice. The anthropometric methods suitable for epidemiologic and clinical studies, include measurements of body mass index (BMI), skin fold thickness and regional bioelectrical impedance analysis.\(^2\)

Bioelectrical impedance analysis (BIA) involves the passage of small, innocuous amounts of alternating current through the body and the measurement of its conductance through body tissues.\(^3\) The conductance is mainly determined by the amount of body water, which is only present in the fat-free mass.\(^4\) As current passes through fat-free mass, the degree of impedance or resistance to electrical conductance gives an estimate of the fat-free mass. Subtracting the fat-free mass from the body mass yields the fat-mass. BIA has an advantage over BMI because the latter is unable to differentiate between individuals whose excess mass is as a result of excess fat or excess fat-free tissue.

Assessment of body fat composition is becoming increasingly important even in developing countries because lifestyle patterns are changing and over nutrition is being increasingly identified within the same communities with high prevalence of under-nutrition.\(^5\) Empirical observation would suggest that Nigerians are getting more exposed to fast food outlets where high calorie, fatty foods are readily served, thus increasing the risk of overweight and obesity. Adolescence, the transitional period between childhood and adulthood has been identified as a vulnerable stage for the risk of overweight and obesity.\(^6\) This system of classification has five strata (1 to 5) in decreasing order of privilege, the upper SEC being classes 1 and 2, while 3 is the middle SEC and 4 and 5 represent the lower SEC.

At the second contact, the questionnaires were retrieved along with signed parental consent. Ethical approval was also obtained from the ethics board of the Lagos University Teaching Hospital (LUTH).

Anthropometry

Measurements of height, weight and percent body fat using Tanita\(^7\) body fat monitor (BF 681) were carried out. Height was measured to the nearest centimeter with the subject barefoot using the Leicester meter.\(^8\) The Tanita body fat monitor/scale model BF-681 was used for bioelectrical impedance analysis and to measure body weight. The Tanita scale looks like a normal bathroom scale. It has four foot pads with electrodes within these pads. Through the footpads, a safe low level (50Hz) electrical signal is passed through the body. The signal flows easily through moisture in muscles and other body tissues but not fat.

The equipment derives the body fat content from impedance recorded and displays it as a percentage of body weight on a digital dial. The equipment also displays the bodyweight in kilogram simultaneously with the percentage body fat. Body mass index was derived using the standard formula of weight in kilograms divided by the height in meters. Fat mass (FM) was derived from multiplying percentage body fat by body mass. Fat free mass (FFM) was derived by subtracting fat mass from body mass.

The classification of overweight and obesity by BMI was based on the age and sex cut-off values recommended by Cole et al.\(^9\) With respect to percentage body fat, overweight and obesity were defined as figures at or above the 85th or
95th percentile values for age and sex respectively based on a nomogram designed by McCarthy et al. 9

Statistical Analysis
The data were analyzed using Microsoft Excel program supplemented by Megastat® version 9.1 statistical package. Measures of statistical location like mean and standard deviation were calculated and rates were determined as appropriate. Continuous variables were compared using Student t-test while proportions used chi-square analysis. In all cases, probability (p) values less than 0.05 were accepted as being statistically significant.

RESULTS
Seven hundred and fifty-three pupils were studied. Of these 377(50.1%) were males and 376(49.9%) were females, giving a male: female ratio of 1:1. One third, 251(33.3%) were recruited from private secondary schools while the rest, 502(66.7%) were from public schools.

Table 1 shows the age-related mean BMI and percent body fat values in male and female subjects. Overall the mean BMI values obtained were significantly higher in girls than boys (18.9 ±7.51 vs 18.1 ±2.72, p = 0.0003). The higher values in girls were reflected in all age groups except age 18, the difference being statistically significant in children aged 11, 12 and 13 years.

Overall, females had about twice the percentage body fat observed in males (18.9 ±7.51 Vs 9.5 ±4.48, p = 0.001). Boys had a consistent drop in percentage body fat through early and middle adolescence with a gentle rise in late adolescence. However for the girls the general trend was in the opposite direction as there was a rise through middle adolescence and a drop in late adolescence (Fig. 1). At all ages the percentage body fat was significantly higher in females except at 10 years of age where they were comparable.

Using the age and sex specific BMI criteria described by Cole et al. 28 (7.5%) females and 11 (2.9%) males were overweight. Thus the prevalence was higher in females compared to males ($\chi^2 = 8.33, p = 0.01$). A similar pattern was seen with regard to obesity with fifteen females (4.0%) and six males (1.6%) being affected ($\chi^2 = 4.46, p < 0.05$). Thirty-nine and twenty-one subjects were overweight and obese respectively thus giving an overall prevalence rate of 5.2% for overweight and 2.8% for obesity.

Using the age and sex specific body fat criteria described by McCarthy et al., 19 subjects (six boys and 13 girls) were found to be overweight, with body fat above the 85th centile. This gave an overall prevalence rate of 2.5% (1.6% for boys and 3.5% for girls). In addition, there were 23 (three boys and 20 girls) obese subjects with percent body fat above the 95th centile giving an overall prevalence rate of 3.1% and sex specific rates of 0.8% and 5.3% for boys and girls respectively. Thus altogether, there were more girls with high percentage body fat than boys. This difference in prevalence rates was statistically significant (8.8% vs. 2.4%, $\chi^2 = 14.59, p = 0.01$).

The degree of concordance between BMI and BIA-derived percentage body fat is shown in Table 2. Eighteen male subjects had BMI above the 85th centile for age (overweight or obese). Of these, eight (44.4%) were confirmed as having high percent body fat while 10 (55.6%) had body fat in the normal range. Similarly, of the 359 subjects with BMI in the normal range, 358 also had body fat in the normal range. Finally, 28 (7.5%) had normal percentage body fat.

Table 1: Mean Body Mass Index and Body Fat of Subjects according to Age and Sex

<table>
<thead>
<tr>
<th>Age (Yr)</th>
<th>Nm</th>
<th>Nf</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>10</td>
<td>26</td>
<td>32</td>
<td>16.8</td>
<td>3.53</td>
<td>17.5</td>
<td>3.31</td>
</tr>
<tr>
<td>11</td>
<td>51</td>
<td>35</td>
<td>16.3</td>
<td>2.1</td>
<td>19.0</td>
<td>3.82</td>
</tr>
<tr>
<td>12</td>
<td>43</td>
<td>62</td>
<td>16.8</td>
<td>1.83</td>
<td>18.1</td>
<td>3.75</td>
</tr>
<tr>
<td>13</td>
<td>52</td>
<td>58</td>
<td>17.7</td>
<td>1.93</td>
<td>18.9</td>
<td>3.97</td>
</tr>
<tr>
<td>14</td>
<td>62</td>
<td>67</td>
<td>18.0</td>
<td>2.24</td>
<td>18.7</td>
<td>2.03</td>
</tr>
<tr>
<td>15</td>
<td>62</td>
<td>63</td>
<td>19.1</td>
<td>2.55</td>
<td>19.4</td>
<td>3.32</td>
</tr>
<tr>
<td>16</td>
<td>41</td>
<td>25</td>
<td>19.6</td>
<td>2.74</td>
<td>20.3</td>
<td>3.67</td>
</tr>
<tr>
<td>17</td>
<td>26</td>
<td>23</td>
<td>19.8</td>
<td>3.4</td>
<td>20.5</td>
<td>3.06</td>
</tr>
<tr>
<td>18</td>
<td>14</td>
<td>11</td>
<td>20.4</td>
<td>1.9</td>
<td>19.5</td>
<td>2.36</td>
</tr>
<tr>
<td>All</td>
<td>377</td>
<td>376</td>
<td>18.1</td>
<td>2.72</td>
<td>18.9</td>
<td>3.41</td>
</tr>
</tbody>
</table>

Nm, number of males. Nf, number of females *p < 0.05; †p = 0.01.

Table 2: Concordance of Body Mass Index with Body Fat in the Determination of Overweight/Obesity

<table>
<thead>
<tr>
<th>BMI &gt; 85&lt;sup&gt;th&lt;/sup&gt; Centile</th>
<th>BMI &lt; 85&lt;sup&gt;th&lt;/sup&gt; Centile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male Subjects</td>
<td></td>
</tr>
<tr>
<td>% BF ≥ 85&lt;sup&gt;th&lt;/sup&gt; centile</td>
<td>8</td>
</tr>
<tr>
<td>% BF &lt; 85&lt;sup&gt;th&lt;/sup&gt; centile</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>18 (100.0)</td>
</tr>
<tr>
<td>Female Subjects</td>
<td></td>
</tr>
<tr>
<td>% BF ≥ 85&lt;sup&gt;th&lt;/sup&gt; centile</td>
<td>32</td>
</tr>
<tr>
<td>% BF &lt; 85&lt;sup&gt;th&lt;/sup&gt; centile</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>42 (100.0)</td>
</tr>
</tbody>
</table>
BMI were confirmed to have high percentage body fat (76.2% vs 44.4%; \chi^2 = 5.71, p < 0.05). This was further buttressed by correlation analysis. There was far better correlation between BMI and percent body fat in females (r = 0.92) than males (r = 0.49).

**DISCUSSION**

**BMI in Males and Females**

The mean BMI of adolescent participants was higher in females than males except at age 18 years. The higher BMI in females corroborates the finding in previous studies worldwide.\(^9\) This pattern reflects differences in the effects of gonadal hormones on body mass of males and females. Oestrogens, being more abundant in females encourage fat deposition. That may be the higher BMI in females during early and mid adolescence. As the enhancing effect of male androgens on muscle bulk increases, a catch-up with female BMI occurs.\(^11\)

**Prevalence Rates of Overweight and Obesity**

The overall prevalence rates of overweight and obesity in the current study were 5.2% and 2.8% respectively. These figures are within the range of 3.4% to 9.3% for overweight and 0.2% and 5.1% for obesity earlier reported for Nigerian adolescents.\(^12\)-\(^14\) They are, however, much lower than 5% to 25% reported from Europe and the United States.\(^15\) The BMI for males in the current study was consistently lower than that reported for the NHANES\(^16\) study in the United States from 10 to 18 years. However it was higher than those reported by earlier Nigerian studies\(^12\)-\(^14\) except in the late adolescent period when it approximated the study by Ansa et al\(^2\) in Calabar. The same pattern was seen between females in the index study whose mean BMI was consistently lower than the NHANES\(^16\) study. On the other hand, there was a close similarity between the results of the index study and the earlier Nigerian studies in the mid to late adolescence years.

Applying percentage body fat criteria yielded prevalence rates of 2.5% and 3.1% for overweight and obesity respectively. The only other Nigerian study that systematically recruited adolescents with the aim of documenting percent body fat derived from BIA reported a much higher prevalence rate of 18% for obesity.\(^14\) Some of the disparity in rates might be explained by demographic differences in study populations. About two-thirds of subjects in our study were from the lower socioeconomic classes in contrast to the Ife study in which the subjects were predominantly of high socioeconomic status. A second difference between our study and the Ife study was that different cut-off levels were used for determining obesity. The Ife study used single cutoff values of 22% for males and 30% for females irrespective of age. In the current study, we preferred a definition based on age and gender of the subjects.\(^9\) This approach appears more physiological and more likely to yield accurate results because body fat proportion is related both to age and gender.

**Relationship between Body Mass Index and Body Fat**

The performance of BMI as a surrogate for body fat was investigated in the study. For male subjects, the prevalence rates of overweight and obesity obtained using BMI were higher than those from percent body fat. More than half of the boys classified as having high BMI levels had normal percent body fat. This demonstrates the pitfall in using BMI as a proxy for body fat in this age group.\(^14\) In the strict sense BMI refers to excess body weight with respect to height. It does not distinguish between those in whom high body mass resulted from excess fat and those in whom it resulted from excess muscle. Thus, both individuals with high body mass as a result of excess fat and those with high muscle mass will have high BMI. This would appear to be the case with the male adolescents in the current study. On the contrary, all the girls who had high BMI also had high percent body fat, the false negativity rate being zero. Thus it is apparent that BMI was more successfully indicative of excess body fat in females than it was in males.

**Limitation**

The major challenge came from private schools where some parents were very reluctant to allow their children participate, necessitating occasional change of already identified potential subjects.

In summary, female adolescents generally have higher fat indices than males. BMI as a surrogate for body fat was more predictive in females than in males. The prevalence rates of overweight and obesity using BMI criteria were within the range earlier reported in the country but lower than reports from the western world. The mean age- and sex-related BMI figures in the current study were generally lower than NHANES\(^16\) standards in the United States.

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**Fig 1:** Age and sex specific BMI and % Body fat in study subjects. BMI, Body mass index; BF, Body fat; F, Female; and M, Male. 

![Graph showing BMI and Body Fat](image-url)
REFERENCES
2. Bioelectrical Impedance Analysis (BIA). www.brianmac.demon.co.uk/fatbia