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

Relations entre l'analyse de l 'Impédance bioélectrique et l'indice de Masse corporelle chez des adolescents citadins du Nigeria

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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 10years to 18years 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.**

RÉSUMÉ

CONTEXTE: L'indice de masse corporelle est souvent utilisé pour évaluer l'adiposité, mais elle ne différencie pas les composantes grasses et non graisseuses de la masse corporelle. Cependant la composante grasse pourrait être évaluée en utilisant l'impédance bioélectrique

OBJECTIF: Le but de cette étude est de correler l'indice de masse corporelle à la graisse dans l'évaluation du surpoids et de l'obésité chez des adolescents nigérians.

METHODES: Des adolescents élèves âgés de 10 à 18 ans ont fait l'objet de cette étude à partir d'écoles secondaires choisies de façon randomisées à Lagos (Nigéria). L'indice de masse corporelle était calculé, et le pourcentage de graisse du corps était mesuré avec l'échelle de gras Tanita Body, de Modèle BF 681.La surcharge pondérale et l'obésité étaient déterminées en utilisant les critères d'âge et de sexe spécifiques pour l'Indice de masse spécifique et pour le graisse corporelle.

RESULTATS: Il y' avait 753 élèves {377 (50,1 %) hommes et 376 (49,9 %) femmes}. Le total des indices de masses corporelles pour les hommes et les femmes étaient respectivement de18.1+/- 2.72 et 18.9+/- 3.41 ($p<0.05$). Les figures correspondantes pour la graisse étaient9.5+/-4.48 et 18.9 +/- 7.51 ($p< 0.05$) . Les trois quarts (76.2 %) des femmes qui ont un indice de masse corporelle dans la catégorie surpoids /obésité ont eu une graisse corporelle élevée par rapport aux 44.4 % des hommes ($p< 0.05$)

CONCLUSION: L'indice de masse corporelle est mieux corrélé à la graisse corporelle chez les filles adolescentes que chez les garçons. **WAJM 2011; 30(2): 99–103.**

Mots Cles: Obésité, Surpoids, Graisse corporelle, Indice de Masse corporelle, Impédance bioélectrique

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Abbreviations: BIA, Bioelectrical Impedance Analysis; **BMI,** Body Mass Index; **FM,** Fat Mass; **FFM,** Fat Free Mass

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.[1]

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.[2] The conductance is mainly determined by the amount of body water, which is only present in the fat-free mass.[3] As current passes through fat-free mass, the degree of impedance or resistance to electrical conductance gives an estimate of the fat-free mass. Subtrac-ting 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.[4] 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 overweight and obesity. [5] The aims of the study therefore were to analyze the body fat composition (and hence obesity) of adolescent Nigerians in secondary schools using BIA technology and to determine association with results obtained using BMI.

SUBJECTS, MATERIALS, AND METHODS

Study Location

The study was school based and conducted in Surulere Local Government Area (LGA) of Lagos State from September through November 2006. Surulere is one of the twenty local government areas in Lagos State, south western Nigeria. Lagos State is the commercial nerve centre of Nigeria and until 1991 hosted the administrative headquarters of Nigeria. The LGA was selected because it is centrally located in the State and is inhabited by a fairly representative cross-section of the Nigerian population. The participants study population consisted of adolescent male and female pupils aged between 10 years and 18 years. The LGA has a total of 30 public secondary schools and 14 registered private secondary schools, each with six classes. Nine schools (six public and three private) were selected at random to represent at least 20% of the number of schools in the local government area. The private schools were all coeducational; three of the public schools were exclusively for boys and three for girls.

Sampling Technique

Separate lists of the private and public institutions were made. The name of each private school was written on a piece of ballot paper. The papers were put in a bag and thoroughly mixed. An independent observer was asked to pick three pieces of paper one at a time, from the bag. A similar process was repeated to identify the participating public schools.

Based on the sample size calculated, 84 pupils were drawn from each school. This number was divided among the six classes giving 14 pupils per class. The class register was then used to select every nth child, the figure 'n' being an integer resulting from the division of the number of pupils in the class by 14. For the coeducational schools, separate lists were used for selecting boys and girls.

Procedure

At the first visit, health talks were given and copies of a self-administered questionnaire were distributed. The questionnaire was designed to record socio-demographic features of the child and parents as well as presence or absence of chronic illnesses in the subjects. The socio-economic class of each child was also ascertained using the methods described by Oyedeji *et al*[6] which takes into account the level of education and occupation of each parent or guardian. 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® body fat monitor (BF 681) were carried out.

Height was measured to the nearest centimeter with the subject barefoot using the Leicester meter.[7] 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 square of 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.*[8] 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±3.41 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,*[6] 28 (7.5%) females and 11 (2.9%) males were overweight. Thus the prevalence was higher in females compared to males (χ^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 (χ^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,*[7] 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%, χ^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 as determined by BIA in the normal range while one subject had high percentage body fat. Similarly, 42 females had BMI above the 85th centile for age (overweight or obese). Of this number, 32 (76.2%) also had high percent body fat while 10 (23.8%) had normal percentage body fat.

In addition, all 334 with normal BMI also had normal percentage body fat.

In comparison with males, therefore, significantly more females who had high

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

			Body Mass Index kgm^{-2}				Body Fat (%)			
			Male		Female		Male		Female	
Age (Yr)	Nm	Nf	Mean	SD	Mean	SD	Mean	SD	Mean	SD
10	26	32	16.8	3.53	17.5	3.31	14.4†	6.94	18.1†	7.93
11	51	35	16.3†	2.1	19.0†	3.82	11.8†	4.5	20.3†	8.72
12	43	62	16.8*	1.83	18.1*	3.75	9.8†	3.2	17.9†	7.97
13	52	58	17.7*	1.93	18.9*	3.97	9.6†	4.08	18.7†	8.95
14	62	67	18	2.24	18.7	2.03	8.3†	3.19	18.7†	5.33
15	62	63	19.1	2.55	19.4	3.32	8.5†	4.48	19.5†	6.73
16	41	25	19.6	2.74	20.3	3.67	7.5†	3.71	20.8†	7.65
17	26	23	19.8	3.4	20.5	3.06	7.5†	3.17	19.2†	7.43
18	14	11	20.4	1.9	19.5	2.36	9.1†	2.82	16.1†	7.13
All	377	376	18.1	2.72	18.9	3.41	9.5	4.48	18.9	7.51

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

	BMI > 85th Centile	BMI < 85th Centile
Male Subjects		
% BF ≥ 85th centile	8	1
% BF < 85th centile	10	358
Total	18 (100.0)	359 (100.0)
Female Subjects		
% BF ≥ 85th centile	32	0
% BF < 85th centile	10	334
Total	42 (100.0)	334 (100.0)

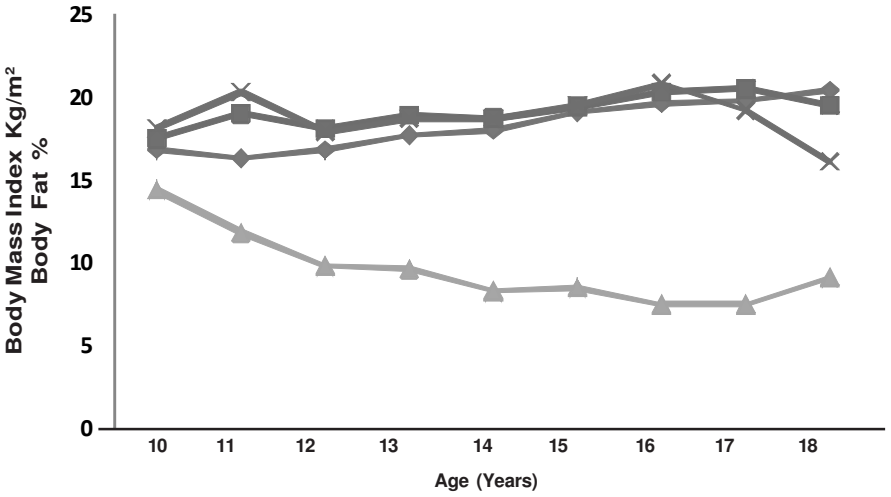

Fig 1: Age and sex specific BMI and % Body fat in study subjects. BMI, Body mass index; BF, Body fat; F, Female; and M, Male. Male BMI Female BMI Male BF Female BF

BMI were confirmed to have high percentage body fat (76.2% vs 44.4%, χ^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.[10] 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 seen 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*[12] 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 cut-off 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.[18] 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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