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Assessment of Body Fat Using Leg-to-leg Bioelectrical Impedance Analysis Method among School Adolescents in Sokoto, North-Western Nigeria

Muhammad Murtala Ahmad[1*], Hamidu Ahmed[1] and Kareem I. Airede[2]

[1]Department of Paediatrics, Usmanu Danfodiyo University Teaching Hospital, Sokoto, Nigeria.
[2]Department of Paediatrics, University of Abuja, Gwagwalada, FCT, Abuja, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors HA and KIA did the study design and author MMA wrote the protocol. Authors MMA and HA did the statistical analysis and literature searches while analyses of study were by all the authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Excess body fat is recognized as a risk factor for cardiovascular diseases, diabetes mellitus and gallbladder diseases. Body mass index (BMI) being the most widely used method of obesity assessment does not differentiate between individuals whose weight is as a result of excess fat or excess muscle mass. This is significant because it is the amount of excess fat rather than mere excess weight that determines the health risks of obesity. Therefore, techniques such as bioelectrical impedance analysis (BIA) that estimate body fat assume more importance in this regard.
Aim: To determine the pattern of body fat and prevalence of obesity, using Leg to leg BIA technique among apparently healthy school adolescents in Sokoto, Nigeria.

**Corresponding author: Email: murisbn@yahoo.com;*

Methodology: A cross sectional study involving 360 subjects (180 males, 180 females, age range 10-18 years) selected from 6 schools within Sokoto metropolis, by a multi-stage random sampling. Subject's weights, heights and BIA were measured. Age and gender specific percentage body fat cut-off values according to McCarthy et al. were used to classify subjects as overweight or obese.
Results: The mean percentage body fat (%BF) values were 8.2±4.1% for the males and 20.0±6.8% for the females (*P*<0.001). Mean BMI of the subjects were 18.3±2.7kg/m^2 for males, and 19.3±3.1 kg/m^2 for the females (*P*=0.001). Steady increase in body fat (%BF) with age was observed among the females, with the %BF values also being higher in the females (*P*<0.001). Based on the BIA method, the prevalence rates for overweight and obesity were 2.5% and 1.7% respectively. With the BMI method however, the prevalence of overweight was 3.3% and 1.4% for obesity. Age 15 years had the highest number of obese subjects (33.3%) whereas; ages 16 and 18 years had the highest number of overweight subjects (22.2% each).
Conclusion: This study has demonstrated the feasibility of using leg-to-leg BIA in body fat assessment in children. It is therefore, recommended that BIA be widely used in clinical practice for obesity studies, because it is a simple and precise tool for body fat assessment in children and adolescents.

Keywords: Adolescents; bioelectrical impedance analysis; body fat; obesity; overweight.

1. INTRODUCTION

Overweight and obesity are assuming epidemic proportions worldwide; contributing to chronic non-communicable diseases [1]. Excess body fat (not mere body weight) is recognized as a risk factor for cardiovascular diseases, diabetes mellitus and gallbladder diseases [2]. Numerous methods, varying in sophistication and expense, have been used to estimate body fat content, but most of the methods are unsuitable for routine clinical assessment [3]. These methods are categorized as: density-based (hydrodensitometry), imaging (dual-energy X-ray absorptiometry- DXA, computerized tomography-CT, magnetic resonance imaging- MRI), bioelectrical impedance and anthropometric (BMI, SFT, waist hip ratio) methods.

Though BMI is the most widely used clinical/anthropometric measure of overweight and obesity, it does not differentiate between individuals whose excessive weight is as a result of excess fat or excessive muscle mass [4]. This is significant because it is the amount of excess fat rather than mere excess weight that determines the health risk of obesity. Hence, techniques that estimate body fat assume more importance in this regard [4].

Leg to leg BIA, is a simple, practical, non-invasive and safe technique of body fat assessment for both children and adults [5,6,7]. It has the potential as an important tool for nutritional assessment, particularly for epidemiologic studies in resource poor settings [8]. The Tanita products are the most popular among this class of instruments and the scales have since been validated for use in paediatric subjects [9,10].

Recent attention has been given to the Ieg-to-leg BIA system, which has several operational advantages when compared to conventional, whole body BIAs [11]. They also offer the advantage of increased speed, ease of measurement as well as high inter-and intra-observer reliability [12,13]. The BIA technique was also observed by Gregory et al. [6] to be perceived as less threatening and better tolerated than the use of skin fold calipers in children under the age of eight, and may be used without difficulty in children as young as three years old.

The newer fat scales measure impedance across body parts (such as leg-to-leg), and the system's four electrodes are in the form of stainless steel; pressure-contact foot pads mounted on the top surface of a platform scale [9,10,14]. This technology requires less time to administer and no special skill or training is required, unlike the whole body BIAs [10,14,15]. This makes it especially useful in assessing body composition in the paediatric population.

Eating, drinking, Hydration status, acute illness, water and electrolyte disturbance and intense exercise may affect the body fat readings. Therefore, the reading should be taken at least two hours after eating or hard exercise [10,16]. BIA is not applicable in conditions with significant body asymmetry as in amputations, unilateral hemiparesis and neuromuscular conditions that produce localized changes in perfusion or tissue atrophy [11].

2. OBJECTIVES

To determine the pattern of body fat and the prevalence of overweight and obesity using Leg to leg BIA, among apparently healthy school adolescents in Sokoto, North-Western Nigeria.

3. METHODOLOGY

It is a cross sectional study, involving three hundred and sixty (360) apparently healthy students aged 10-18 years, selected from 6 schools (3 public, 3 private) within Sokoto metropolis (State capital), by a multi-stage random sampling technique. All secondary schools within Sokoto metropolis were stratified into public and private schools from which 3 schools each were selected by random sampling based on the 3 LGAs within the state capital.

Sample size was calculated using the formula: $N= z^2pq \div d^2$. The prevalence rate (p) used was based on the highest prevalence of 18% reported among Nigerian children and adolescents, using a similar method of bioelectrical impedance analysis [5]. Thus, $N = (1.96)^2 \times 0.18 \times (1- 0.18) \div 0.05 = 226$. (Therefore, 360 subjects were recruited).

Anthropometric measurements of weight and height were carried out on each subject, from which BMI was calculated. Leg to leg BIA technique was employed using Tanita Body fat scale (model UM-030, Tanita, UK Ltd) to assess the body fat content according to the manufacturer's instructions. Subjects were measured while standing erect, on the analyzers footpads, in bare feet and wearing light clothing. As the subjects bare feet make pressure contact with the electrodes and the digital scale, harmless, low level (50 kHz) alternating electrical current passes through the body. The current flows easily through the fluids contained in muscles and other body tissues but not fat. This measures electrical conductivity by electrical impedance, thereby providing an assessment of the body composition based on the principle that conductivity is far greater in the fat-free mass than in fat mass [17].

Measurements were taken between 9am and 11am, when the pupils have settled in class after the exercise of walking to school. Age and gender specific percentage body fat cut-off values according to McCarthy et al. [18], were used to classify subjects as overweight or obese. Overweight and obesity were respectively defined as %BF values $\geq 85^{th}$ to $<95^{th}$ and $\geq 95^{th}$ percentiles of the body fat reference curves, based on age and gender.

Socioeconomic classification (SEC) was based on the method described by Oyedeji [19]. Socio-economic index scores were awarded based on parental occupation and educational attainment. For each of maternal and paternal occupation and educational attainment, scores from 1 to 5 (in descending order of advantage) were awarded. The mean of the 4 scores (to the nearest whole number) was the child's social class. SEC 1 and 2 were regarded as upper, SEC 3 as middle, while SEC 4 and 5 as the lower social class [19]. Data was analyzed using the statistical package for social studies (SPSS) version 17.0, statistical software.

Ethical approval for the study was obtained from the Ethics Committee of Usmanu Danfodiyo University Teaching Hospital, Sokoto, the Sokoto State Ministry of Education and the respective school authorities concerned. Consent was also obtained from the parents/guardians of the students from enrolled day schools.

4. RESULTS

Three hundred and sixty (360) students were selected from 6 schools within Sokoto metropolis, with a male to female ratio was 1:1. Majority of the studied subjects (47.5%) were from middle socioeconomic class (SEC), with a fair distribution between the public and private schools. Only 24.2% of the subjects belonged to the upper SEC stratum, out of which 65 (74.7%) were from private schools. Among the overweight/obese subjects, majority belonged to the middle SEC (47.1%) with only 17.6% of them coming from the upper SEC families as shown in Table 1.

The mean %BF values were 8.2±4.1% for the males, and 20.0±6.8% for the females ($P<0.001$). Mean BMI of the study subjects were 18.3±2.7 kg/m^2 for males, and 19.3±3.1 kg/m^2 for the females ($P=0.001$). Steady increase in body fat (%BF) with age was observed mainly among the females. The %BF varied significantly with gender, being higher in females than males ($P<0.001$) as depicted in Table 2.

Table 1. Distribution of overweight and obese subjects according to socio-economic class

SEC	Public schools	Private schools	Total (%)
Upper	0	3	3 (17.6)
Middle	3	5	8 (47.1)
Lower	4	2	6 (35.3)
Total	7	10	17 (100)

SEC= socioeconomic class

Based on the BIA method, the prevalence of overweight was 2.5% and that of obesity was 1.7%. Whereas, based on the BMI method; the prevalence rates 3.3% and 1.4% for overweight and obesity respectively (Table 3). The correlation coefficient between the two methods is shown in Table 4. Overweight was more prevalent among the females (61.5% of the overweight subjects) with equal gender prevalence for obesity. Age 15 years had the highest number of obese subjects (33.3% of the obese subjects) whereas; ages 16 and 18 years had the highest number of overweight subjects (22.2% each).

The %BF values were generally lower in our subjects compared to the values reported by McCarthy et al. among children in the UK. Females showed more progressive increase in percentage body fat with age as shown.

5. DISCUSSION

Since the pathology associated with obesity is driven by the excess fat mass, the ideal assessment tool should directly assess adiposity. Many of the available tools that can do that are complex and expensive [1]. Earlier BIA systems measure total body electrical conductivity but were bulky; require technician placement of arm and leg gel electrodes, a suitable location for recumbent measurement and a separate scale for measurement of body weight [10].

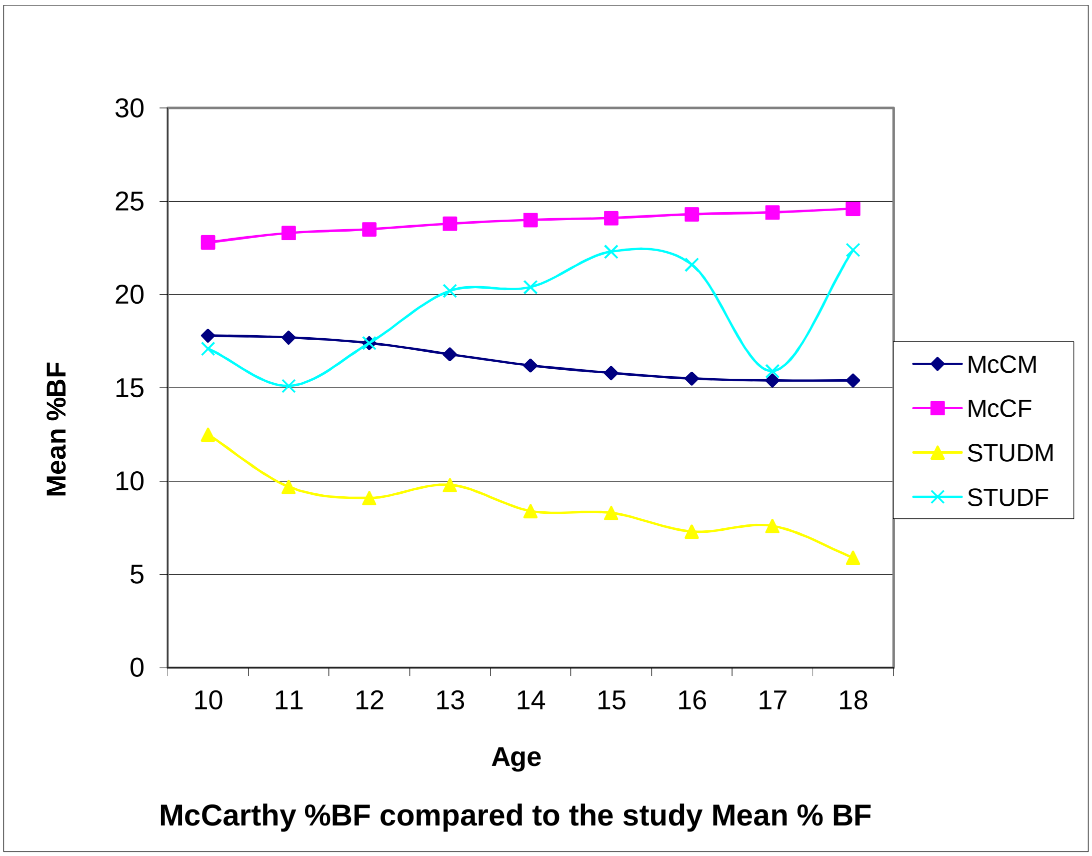

Fig. 1. Comparison of the mean values of percentage body fat among the subjects with those of McCarthy et al. [18]

McCM= mean %BF for males in McCarthy study; McCF= mean for %BF females in McCarthy study; STUDM= mean %BF for males in present study; STUDF= mean %BF for females in present study

Table 2. mean percentage body fat (SD) according to age and gender

Age(yr)	Males	Body fat (%)	Females	Body fat (%)	T	*P*
	N	Mean (±SD)	N	Mean (±SD)		
10	3	12.53±0.71	2	17.10±1.84	-3.194	0.193
11	5	9.66±3.48	8	15.05±7.38	-1.528	0.201
12	13	9.05±2.94	19	17.36±7.01	-4.057	0.002
13	28	9.80±4.62	18	20.22±5.57	-5.970	<0.001
14	24	8.39±2.20	30	20.40±5.83	-8.535	<0.001
I5	24	8.26±5.35	31	22.28±6.24	-7.020	<0.001
16	35	7.29±4.58	30	21.65±4.73	-10.782	<0.001
17	32	7.55±3.53	23	15.93±6.88	-5.907	<0.001
18	16	5.94±3.00	19	22.44±9.67	-5.810	<0.001
Total	180	8.23±4.10	180	19.97±6.85	19.817	<0.001

%BF= percentage body fat; SD= standard deviation

Table 3. Prevalence of overweight and obesity based on BIA & BMI methods

	Overweight (OW)	Obese (OB)	Combined (OW+OB)
Method used	N (%)	N (%)	N (%)
BMI	12 (3.3)	5 (1.4)	17 (4.7%)
BIA	9 (2.5)	6 (1.7)	15 (4.2%)

BMI = body mass index; BIA = bioelectrical impedance
X^2= 0.765, df = 2, P= 0.682

Table 4. Gender-related correlation coefficients (r) between the two methods

	Gender	N	R	*P*-value
BIA Vs BMI	Males	180	0.56	<0.001
	Females	180	0.87	<0.001

Vs = Versus

Leg to leg BIA, being one of the simple and cheap tools developed work on the same principle, but measure impedance across two body regions (leg-to-leg). Recent attention has been given to the Ieg-to-leg BIA system, which has several operational advantages when compared to conventional, whole body BIAs [11]. They also offer the advantage of increased speed, ease of measurement as well as high inter-and intra-observer reliability [12,13].

Sung et al. [9] have compared BIA with dual x-ray absorptiometry (DXA) method in the assessment of fat mass and %BF, in 49 Hong Kong children aged 7 to 16years and found 95% limit of agreement between the BIA and DXA methods. They concluded that the BIA method is a valid alternative to DXA for the measurement of body fat.

Pecoraro et al. [20] studied the correlation of BMI and SFT with the bioimpedance in fat mass prediction in a cohort of 6 year-old Italian children and reported significant positive correlation between the fat mass measured with BIA and BMI (r = 0.92, p<0.00l) and with triceps skin fold thickness (SFT), r= 0.79, p<0.00l). They concluded that the BIA is a useful method and that it may be more precise than the SFT for measuring fat mass in children.

Yu et al. [21] have also reported significant correlation between BIA and DXA among 103 overweight/obese Korean elementary students. Another study on Chinese children aged 11-17 years compared BIA with SFT anthropometric predictions and found BIA to be a reliable and acceptably accurate method [16].

The mean percentage body fat (%BF) for boys in this study was found to be highest at 10years and leveled off at 14years. This finding is consistent with that of Sung et al. [9] in Hong Kong, which showed an increase in %BF in boys from age 8, peaked at age 11 and leveled off at age 14 years. In contrast to the %BF values in boys, the mean %BF values in girls increased steadily and significantly with increase in age. This observed increase in %BF with age in the females is in agreement with the reports by Owa and Adejiyugbe [5], Sung et al. [9] as well as that of McCarthy et al. [18], using similar BIA methods for the percentage body fat assessment.

The mean %BF values in the present study were lower than what was reported by Owa and Adejuyigbe [5], for both males and females respectively. However, the subjects in their study were said to be drawn from a relatively 'privileged' section of their community (University community). Also, whereas Owa's study used whole body/arm-to-leg BIA method among 5-15 year old subjects, our study used segmental/leg to leg BIA among 10 to 18 years old subjects.

The mean %BF for age values appeared less consisted in the males, not varying proportionately with increase in age. However, in the females, the mean %BF showed more steady increase with age. This gender specific pattern was similar to the findings from South-Western Nigeria [22] and among Hong Kong children [9]. This is may be due to the effect of sex hormone's induced sexual dimorphism. The females lay down fat as a natural part of the ontogeny of their sexual and reproductive physiology, whereas the males gain proportionately more muscle mass rather than fat [18,23,24].

Based on the two methods of assessment used in this study, the prevalence of overweight and obesity appeared to be low compared to some previous reports among children from the South-Western part of Nigeria [3,5,25]. Our finding is also consistent with the reports that a high prevalence of obesity is uncommon in developing countries [2,26]. However, Morgre et al. [27] have recently reported a prevalence of 17.4% (for both overweight and obesity), using BMI method among 15-14year olds in Ghana. Larger scale surveys are therefore needed to ascertain some of these facts.

Highest frequencies of overweight/obesity in the female subjects were recorded among age group 18years, followed by those aged 15 and 16 years. This finding is consistent with that of Akesode et al. [3] who demonstrated highest frequencies of obesity and overweight among female age groups 18 and 17 years respectively.

When both overweight and obese subjects were combined in terms of socioeconomic classification, only 17.6% of them came from the upper SEC families while majority (47.1%) were from the middle socioeconomic class, though this distribution was not statistically significant. Therefore, our finding did not favour upper SEC as a significant risk factor for overweight and obesity in the studied community. Therefore, further studies are needed on the risk factors for obesity in our environment.

6. CONCLUSION

This study has demonstrated a low prevalence of overweight and obesity in terms of percentage body fat and BMI. It has also shown the feasibility of using leg-to-leg BIA in body fat assessment in our setting. Further research is needed to establish the body fat cut-offs associated with health risks among African children.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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