Comparison between Bioelectric Impedance Analyzer Device and Anthropometry for the Evaluation of Body Composition among Young Adult Students of Paschim Medinipur, West Bengal

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ABSTRACT: Body composition is mainly the presence of fat mass and fat free mass in the human body according to the two-compartment model. This method is widely used because of the major cardiovascular and metabolic health issues related to fat distribution. Body composition assessments are regularly used to diagnose the nutritional health status of an individual. Studies found various number of differences between the methods that are used to assess the body composition. The principal objective of the study is to found the difference between the estimation of body composition variables using body impedance analysis (BIA) and anthropometry. A total 201 adult male students aged between 18-28 years were studied. The data collected were height, weight, waist circumference (WC), bicep skinfold, triceps skinfold, suprailliac skinfold, subscapular skinfold. An OMRON full body sensor body composition monitor and scale – HBF-510 was used to assess the percentage body fat (PBF) of the study participants. Significant mean difference found in fat mass (FM), fat free mass (FFM) and PBF using anthropometry and BIA. Also, correlation of different variables to diagnose obesity using BIA and anthropometry between the methods was found in this study. The prevalence of obesity exhibits a higher rate using BMI than BIA measured FM. It is important to decide which method to use for more accuracy and feasibility in a population-based study.

INTRODUCTION

Body composition is mainly the presence of fat mass and fat free mass in the human body according to the two-compartment model. Two compartment model is one of the most prevalent methods to assess the body composition first introduced in the 1950s (Siri,1956; Brozek *et al*., 1963). This method is widely used because of the major cardiovascular and metabolic health issues related to fat distribution (Manolopoulos *et al*., 2010). Also, it is an established fact that fatty acids influence a range of diseases like type 2 diabetes, inflammatory disease and many types of cancer (Calder, 2015). According to two compartment model there are five major variables when we measure body composition. These are Percentage body fat (PBF), Fat mass (FM), Fat free mass (FFM), Fat mass index (FMI) and Fat free mass index (FFMI). Fat mass is the fat stored in the vital organs like heart, kidney, lungs, liver, marrows, intestine, spleen, muscles and lipid rich tissue which is called the essential fat. The essential fats are important for a

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body to function properly. Fat free mass (FFM) is just the mass of the body without the fat mass. The term FFM and lean body mass (LBM) is sometimes used as interchangeably. But this is not correct as the lipid in cellular membranes are included in LBM, though this accounts for only a small fraction of total body weight (3.00% in men, 5.00% in women). Also, sometimes the bone mass has been included in the LBM (Yu *et al*., 2013).

Body composition assessments are regularly used to diagnose the nutritional health status of an individual including being overweight, obese, osteoporosis, sarcopenia and sarcopenic obesity (Holmes and Racette, 2021). Obesity is a major global health burden of chronic diseases and nearly half a billion of world's population is considered to be overweight or obese. The pandemic of obesity is so prevalent that the term 'globesity' has been given to the present situation (Mukhopadhyay *et al*., 2010). Thus, the diagnosis of overweight and obesity is of paramount necessity most importantly among the adolescents and adults. Though BMI is a useful method for this but it cannot differentiate between fat mass and fat free mass. Also, the percentage of body fat is also remains unknown through BMI. Therefore, body composition methods are sine qua non for a detailed description of the fat and non-fat make-up of the body. The composition of fat, non-fat, muscle, skeletal and water components in the body are 'highly informative in the diagnosis, management and treatment of several nutrition-related conditions that impact individual and population health' (Holmes and Racette, 2021).

There are various direct and indirect methods to assess the body composition of an individual or a population. It is the objective that decides which kind of method is most suitable for the particular use. Some of the methods are body mass index (BMI), skinfold measurements, dual X-ray absorptiometry (DXA), bioelectric impedance analysis (BIA), hydrodensiomentry, digital image analysis, air displacement plethysmography (ADP), computed tomography (CT) and magnetic resonance imaging (MRI). There has many pros and cons for each method as well as necessity of various equipment (Table 1).

TABLE 1

Overview of body composition assessment technique requirements, pros and cons (Holmes and Racette, 2021)

Assessment Method	Equipment needed	Time needed	Pros	Cons
Body Mass Index (BMI)	• Stadiometer • scale	≤ 3 min	• Quick • Simple • Inexpensive	• Does not differentiate between FM and FFM
Circumferences	• Flexible tape measure	≤ 5 min	• Quick • Simple • Inexpensive portable	• Does not differentiate between FM and FFM
Skinfolds	• skinfold calipers	10-20 min	• Accurate when performed by a • skilled assessor • Inexpensive • Portable	• Technical expertise required to minimize intra- and inter-observer variability • Close proximity & skin contact required with various body regions
Bioelectric Impedance Analysis (BIA)	• BIA instrument	≤ 5 min	• Quantifies regional body composition • Simple for assessor & individual being assessed • Portable	• Accuracy varies across instruments • Contradicted in individual with implantable electronic devices • Limited validation research
Digital Image Analysis	• 3D scanner	1-2 min	• Quick • Simple • Portable	• Tight-fitting clothing must be worn

Air Displacement Plethysmography (ADP)	• BOD POD instrument • Stadiometer • Scale	≤ 10 min	• Automated minimal technical expertise required	• Expensive • Large space required • Minimal and tight-fitting clothing required
Dual-Energy Xray Absorptiometry (DXA)	• DXA machine	10-30 min	• Quantifies bone structure details • High reliability	• Expensive • Personal training & certification required • Low-level radiation exposure
Computed Tomography (CT)	• CT scanner	Varies on the region being scanned	• Quantifies tissue cross-sectional area • High validity	• Expensive • Training & certification required
Magnetic Resonance Imaging (MRI)	• MRI scanner • Required software	Varies on the region being scanned	• Quantifies regional FM • High validity	• Expensive • Training & certification required
Hydrostatic Weighing (HW)	• Large tank filled with water • Chair suspended from a scale above the tank • Spirometer • Metabolic cart of nitrogen washout system • Scale • Nose clips	30-45 min	• Accurate • Validated	• Expensive, sophisticated equipment, set-up & maintenance required • Technical expertise required • Uncomfortable for participant • Not feasible for population study

Among all of the methods Anthropometry (BMI, circumferences and skinfolds) and BIA is most widely used because of their accessibility and minimum professional training and assistance requirement. BIA machines are smaller and some being hand held, faster result producer, relatively low cost. And most important these machines can be used in a population study to accurately assess the body composition. The skinfold method is being widely used method of body composition till date. With the help of mathematical equations, we can manually calculate the percentage body fat (PBF), fat mass and fat free mass using different skinfold measurement for adults, adolescents as well as children (Sen and Mondal, 2013; Klimek-Piotrowska *et al*., 2015; Gharib and Rasheed, 2009; Banik *et al*., 2016). The present study is focused on these two methods: Anthropometry and BIA, to the assessment of body composition.

World Health Organization (WHO, 1998) has defined a cut-off for obesity based on PBF >25% in men and >35% in women (WHO, 1995). Though there are studies those defined cut-off point for obesity based on PBF different than WHO for various geographical regions made up to ethnic groups (Heo *et al*., 2012; Hung *et al*., 2017), but the one given by WHO,'98 is more widely acceptable and used for population study. World Health Organization has also given specific cut-off points for worldwide and Asia-pacific population based on BMI (WHO, 2000; WHO, 1998). Other simple anthropometric measures like waist height ratio (WHtR) and waist circumference (WC) are quick, easy to use technique for the assessment of central adiposity, and can be surrogate indicators of disease risk in both adults and children (Day et al., 2018) based on the cut-off given by Hsieh and Muto (2004) and WHO (2008).

Globally, 1.9 billion and 609 million adults were overweight and obese, respectively in 2015 (Chooi *et al*., 2019). In the United States overweight or obese population has transcended the normal population by 2:1 ratio and severe obesity has gone up to 7.00%. Nearly 85.00% of the American adults will be overweight or obese by 2030. Worldwide 37.00% of men and 38.00% of the women are estimated to have higher BMI than 25 kg/m^2. In the Asian countries the condition is not so severe but still the presence of obesity is increasing in an alarming rate. In Pakistan 14.00% men and women are obese, in China 10.00% women are obese (Smith and Smith, 2016). In India 15.00% of the women are overweight or obese

according to National Family Health Survey (NFHS-3) (Kalra and Unnaikrishnan, 2012). The prevalence rate of obesity and central obesity in India varies from 11.80% - 31.30% and 16.90% - 36.30%, respectively (Ahirwar and Mondal, 2019). In North 24 Parganas, West Bengal 29.30% men are overweight (Roy *et al*., 2016). In the Hoogly district, West Bengal prevalence of obesity is 28.60% and 26.6% among men and women, respectively (Basu *et al*., 2013).

A study in Melbourne, Australia shows that the average FM in adults is 29.63 kg and 29.32 kg using DXA and BIA method respectively. The average FFM is 57.65 kg and 58.90 kg using DXA and BIA method, respectively. Also, a significant correlation was found between WC and BIA FFM (kg) as well as WHtR and BIA FFM (kg) (Day *et al*., 2018). Another study in Korea among the obese elementary school children found the average PBF 40.18% and 38.67% using BIA and DXA, respectively. The average FM and FFM was 20.40 kg, 19.63 kg and 30.37 kg, 31.14 kg using BIA and DXA, respectively. There was significant correlation of FM and FFM between the two methos (Yu *et al*., 2010). In Spain, a study among female students found that the average FM is 16.03 kg, 14.33 kg and 17.67 kg using DXA, BIA and Anthropometry method, respectively. The average FFM is 39.29 kg, 42.07 kg and 38.74 kg using DXA, BIA and Anthropometry method, respectively (Alburquerque-Sendin *et al*., 2010). Das *et al*., 2012 in Paschim Medinipur, West Bengal among the rural Bauri women found the mean FM, FFM and PBF is 12.88 kg, 32.43 kg and 27.91%, respectively using anthropometry (Das *et al*., 2012).

The literature clearly shows that there is a difference of estimation of FM, FFM and PBF between different methods. Anthropometry is most widely used method till date to assess the body composition because of its simple and inexpensive use most importantly in a population study. Whereas, BIA is another method which can assess the body composition relatively more accurate than anthropometry, but it is not so inexpensive and easy to use compared to the later. And in India there is a scarcity in the literature when it comes to the comparison between these two methods. The present study is explicitly aimed at that particular intent. The principal objective of the study is to found the difference of estimation of body composition variables between BIA and anthropometry. Also, the correlation between different variables to measure obesity among the studied participants.

MATERIALS & METHODS

Study Area and Subjects

The present cross-sectional study was conducted during May 2022, among the adult male students of Midnapore town, Paschim Medinipur, West Bengal. A total of 201 adult male participants aged between 18-28 years were studied. Purposive sampling method was used to select the study participants. The procedure and objectives were clearly mentioned to all of the participants. Also, verbal consent was given by all of the subjects before the data collection. Also, a written permission was obtained from the head of the department of Anthropology, Vidyasagar University before the beginning of the study.

Anthropometric Measurements

Anthropometric measurements were taken as per standard techniques (Lohman *et al*.,1988). Height (HT), weight (WT), waist circumference (WC), biceps skinfold (BSF), triceps skinfold (TSF), subscapular skinfold (SSF) and suprailliac skinfold (SISF) measurement were taken. Height was measured using Martin's anthropometric rod to the nearest 0.1 cm. Weight was taken using a standard spring balance weighing machine to the nearest 0.5 kg.

Bioelectric Impedance Analysis

An OMRON full body sensor body composition monitor and scale – HBF-510 was used to assess the PBF of the study participants. The BIA machine estimates the PBF by sending an extremely weak electrical current of 50 kHz and less than 500 μA through the body to determine the amount of water in each tissue. The participator cannot feel any electrical current. The muscles, blood, bones and body tissues with high water content conduct electricity easily. On the other hand, body fat does not store much water, therefore has little electric conductivity. The measurement was taken by giving a very detailed and careful assistance. At first the necessary details

(height, date of birth and gender) were put in the display unit of the machine. Then the subject stood on the machine with his knees and back straight and looking straight ahead. Then he raised his arms horizontally and extended his elbows straight to form a 90^0 angle to his body by holding the display unit which was attached to the BIA machine. The palm and the feet were properly positioned with the electrodes which sent the electric current to the body. In that position the subject stood approximately 60 seconds and then the results were noted down from the display unit. This exact method has been repeated for each participant.

Assessment of Body Composition

TABLE 2

The following equations were used

Variable	Equation
BMI	weight (kg) / height (m^2)
Waist height ratio	waist circumference (cm) / height (cm)
Density (for men)	[1.1765 - {0.0744 x log (sum of 4 skinfold measurements)]
Body Fat (%)	{(4.95/Density) – 4.5} x 100
Fat mass (kg)	weight (kg) x (body fat% / 100)
Fat free mass (kg)	weight (kg) – Fat mass (kg)

TABLE 3

To determine the frequency of obesity the following cut-off values were used

Variables	Male	Female	Reference
WC (cm)	$\geq$ 90	$\geq$ 80	WHO, 2008
WHtR	$\geq$ 0.5	$\geq$ 0.5	Hsieh and Muto, 2004
PBF (%)	25	35	WHO, 1995

TABLE 4

The international classification of adult chronic energy deficient (CED), overweight and obesity according to BMI (kg/m^2)

Category	WHO (1995) cut-off points	Asia Pacific (2000) cut-off points
CED	$\leq$ 18.49	$\leq$18.49
Normal	18.50-24.99	18.50-22.99
Overweight	25.00-29.99	23.00-24.99
Obese	$\geq$30.00	$\geq$25

*CED- Chronic energy deficiency

Statistical Analysis

All statistical analysis were conducted using IBM SPSS (version 26.0). Descriptive characteristics are displayed as means $\pm$ SD for the total samples. The correlations between BIA, Anthropometry, WHtR and WC were analysed using Pearson's correlation. A p-value of $p<0.05$ was considered to be statistically significant. Subject's paired sample t-test were done to compare statistically significant difference between Anthropometry and BIA method of FM, FFM and PBF measures.

RESULTS

TABLE 5

Anthropometric and derived variables (Mean $\pm$ SD) among the studied participants

Variable	Mean ± SD
Age (Years)	22.23 ± 1.78
Height (cm)	166.69 ± 6.26
Weight (kg)	60.23 ± 10.44
BMI (kg/m^2)	21.72 ± 3.38
WC	77.53 ± 11.60
WHtR	0.47 ± 0.069
Bicep skinfold	6.86 ± 3.18
Tricep skinfold	12.12 ± 5.00
Subscapular skinfold	17.16 ± 7.00
Suprailliac skinofold	15.72 ± 7.80

NOTE: BMI: Body Mass Index, WC: Waist Circumference, WHtR: Waist-height ratio.

Table 5 shows the descriptive characteristics (mean $\pm$ SD) of the studied participants. The average age of the participants was 22.23 $\pm$ 1.78 years and average BMI was 21.72 $\pm$ 3.38 kg/m^2. The average WC and WHtR was 77.53 and 0.47, respectively.

TABLE 6

Fat mass, fat free mass and percentage body fat (mean $\pm$ SD), as measured by anthropometry and BIA among studied participants

Method	Mean ± SD	Mean difference
Fat mass (kg)		
Anthropometry	12.99 ± 5.53	1.67 $\pm$ 1.86 ($p<0.001$)
BIA	11.32 ± 5.07	
Fat free mass (kg)		
Anthropometry	47.23 ± 5.89	1.67 $\pm$ 1.86 ($p<0.001$)
BIA	48.90 ± 6.47	
Bodyfat (%)		
Anthropometry	20.83 ± 5.89	2.69 $\pm$ 3.07 ($p<0.001$)
BIA	18.14 ± 5.62	

Table 6 displays the mean $\pm$ SD of FM, FFM and PBF *Frequency of obesity using WHtR, WC, BMI (Normal <25 kg/m^2; Overweight / Obese $\geq$25kg/m^2) and Bodyfat% among the studied participants*, as measured by the anthropometry and BIA. Anthropometry overestimated the FM by 1.67 kg and as a result underestimated FFM by 1.67 kg, compared

to BIA. The average PBF was 20.83% and 18.14% using anthropometry and BIA, respectively. Anthropometry overestimated PBF by 2.69% compared to BIA. The mean difference between two methods was highly significant.

TABLE 7

The prevalence of obesity and bodyfat among the studied participants

Variables and Methods	Normal		Overweight/Obese	
	N	%	N	%
BMI	163	81.1	38	18.9
WHtR	134	66.7	67	33.3
WC (cm)	175	87.1	26	12.9
Bodyfat % by anthropometry	151	75.1	50	24.9
Bodyfat % by BIA	177	88.1	24	11.9

Table 7 shows the frequency of obesity using WHtR, WC, BMI and Bodyfat percentage among the studied participants. Body mass index (WHO,'98) cut off estimates a higher prevalence of obesity (18.90%) than PBF using BIA (11.90%) and a lower prevalence of obesity than PBF using anthropometry (24.9%). Waist circumference, WHtR shows the prevalence of central obesity 12.90% and 33.30%.

Table 8 displays the correlation between BIA, anthropometry, WC and WHtR for fat mass, fat free mass divided in BMI category among the studied participants. For FM and FFM all of the variables are significantly correlated ($p < 0.001$) for the overall category. For FFM there is no significant relation found between the BIA, WHtR and WC for the CED, normal and obese category.

DISCUSSION

The present study found that based on PBF the obesity prevalence rate is 11.90% when measured with BIA and 24.90% when measured with anthropometry. The mean PBF measured by BIA (18.14%), in our study was very lower than Saudi adults (31.10%), also the obesity prevalence rate was much lower than that of Saudi adult males (11.90% vs 57.90%) (Habib, 2013). A study in Korea also shows a very higher mean PBF (40.20%) and FM (20.40 kg) than the present study (18.14% and 11.32 kg, respectively). Consequently, the mean FFM was much lower in the Korean adults (30.40 kg vs 48.90 kg) (YU *et al*., 2010). A study in Australia displays that BIA method underestimated the FM by 0.30 kg compared with DXA, our study also shows a discrepancy of 1.60 kg in FM between BIA and anthropometry (Day *et al*., 2018). In Estonia, there was also found inconsistency between different kind of body composition methods like DXA, BIA and anthropometry (Lintsi *et al*., 2004). In Alabama among the African American and Caucasian American women anthropometry overestimated the PBF than DXA, which is similar to the present study using BIA is the place of DXA (Cedillo *et al*., 2022). Das et al., 2012 conducted a study among Bauri women in Paschim Medinipur, where they used anthropometry and found the mean FM, FFM and PBF was 12.88 kg, 32.43 kg and 27.91%, respectively (Das *et al*., 2012). Our present study also done in that same region among the young men and found similar mean FM (12.99 kg) but mean FFM (47.23 kg) was higher and mean PBF (20.83%) was lower. Thakur et al., 2022 in Pune found

TABLE 8

Correlation matrix (Pearson's correlation) between BIA, anthropometry, WC and WHtR for fat mass, fat free mass divided in BMI category (Asia Pacific, 2000) among the studied participants

Variable	CED (N=33)	Normal (N=95)	Overweight/Obese (N=73)	Overall (N=201)
		Fat mass		
BIA & Anthropometry	0.759***	0.836***	0.863***	0.942***
BIA & WHtR	-0.353*	0.528***	0.405***	0.595***
BIA & WC	-0.305	0.597***	0.510***	0.663***
Anthropometry & WHtR	-0.448**	0.504***	0.432***	0.617***
Anthropometry & WC	-0.384	0.628***	0.550***	0.663***
		Fat free mass		
BIA & Anthropometry	0.817***	0.879**	0.850***	0.943***
BIA & WHtR	0.329	0.005	0.093	0.518***
BIA & WC	0.319	0.001	0.051	0.502***
Anthropometry & WHtR	0.419**	0.026	0.030	0.492***
Anthropometry & WC	0.398**	-0.011	-0.027	0.467***

NOTE: *p < 0.05; ** p < 0.01; ***p< 0.001 CED= Chronic Energy Deficient; N= Number of participants.

a quite similar mean difference (1.06% vs 1.67%) in PBF between the BIA and anthropometry methods. In that study contrary to our present study, anthropometry underestimates the mean PBF compared to BIA. Also, they found correlation of the PBF measure between the two methods, a fact which is also evident in the present study (Thakur *et al*., 2022).

CONCLUSION

Most of the previous studies on obesity were primarily focused on the general obesity (BMI) and central obesity (WC, WHtR) measures. The investigation on the body composition of the adult student population were scanty specially using BIA. The present study found that BMI does not properly estimate the obesity measure when compared to BIA. It is clear from the literature on this topic that BIA is more accurate than Anthropometry. Though we can assess easily and quickly through anthropometry but it cannot tell us about the difference between fat and non-fat components, a job that BIA does explicitly. But the literature also tells us that BIA also has some fundamental dissimilarities when compared to other advanced methods like DXA, MRI and CT, but BIA is cheaper and more portable than those methods and does a decent assessment of the body composition specially when it comes to population studies. The obesity prevalence rate was much higher when used BMI than BIA measured FM. The anthropometric equations need to be calibrated with the help of new and advanced methods because no one can argue against the availability and feasibility of this method.

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