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Original Research Article

Application of bioelectrical impedance analysis and anthropometry as interchangeable methods to assess body composition of sportspersons

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Abstract

Objective: The study was conducted to find application of bioelectrical impedance analysis and anthropometry as interchangeable methods to assess body composition of sportspersons.
Design: A 4 months long cross-sectional study was conducted at Sports Authority of India during pre-competition period.
Method: 83 national and international level players from Sports Authority of India with age 18-25 years were selected as participants and body fat percentage was estimated using both the techniques following strict adherence to pre-measurement criteria. Descriptive statistics were calculated for all the parameters. Bland-Altman analysis was carried out to compare the methods.
Result*:* Internal consistency of the data was confirmed by Pearson's correlation value of 0.739 at $p \leq 0.05$. Mean body fat percentage from anthropometry came out to be 13.08±5.00 and from BIA 14.78±9.29. Mean difference between the body fat percent values between anthropometry and BIA was found to be 1.70±6.53. Limits of agreement from Bland-Altman plot were found to be clinically significant with values from -14.51 to 11.11 at 95% confidence interval suggesting large discrepancies.
Discussion: Based upon the findings of the study, it is not advisable to use anthropometry and BIA as interchangeable methods of body fat estimation however results need to be validated with further studies in future. Out of the two methods, BIA involves certain pre-measurement criteria like players falling in normal BMI ranges with emptied bladder, no vigorous training and food beverage intake before assessment. As, a result the study suggests anthropometry as a preferred method for body fat estimation of sportspersons.
Keywords: Anthropometry, body composition, Durnin and Womersley, method comparison, Bland Altman.

1. Introduction

The relative proportion of fat and fat free tissue in the human body is known as body composition. The analysis of this particular parameter in the field of physical fitness and sports science has been a topic of considerable interest as, it can alter athletic performance to some extent, keeping other factors into account while on the other hand athletic training can also cause alteration of body composition [1].

As studied by Buśko and Lipińska (2012), relatively high fat content if found in volleyball players can hinder rapid and varied movements [2]. For gymnasts it can affect lifting the body up against gravity while the same fat provides added buoyancy to swimmers [3-5]. It has also been mentioned in one of the studies that endurance declines with a low fat levels among track and field runners and in marathon runners also, it is the stored form of fat i.e. glycogen which fulfils prolonged energy requirements [6]. Similarly, in another study, female runners were followed up quarterly for a period of one year and an association between lower fat content and injury risk was found [7].

When talking about fat free mass, specifically the muscle content, it is a well established fact that the continuous supply of energy comes from the muscle mass only. Whether it is track and field events, power games, endurance games like swimming, rowing and many others [8].

In team events like football and basketball fat and fat free mass distribution changes with the playing positions. Goalkeepers possess the highest amount of fat percentage followed by midfielders, backs and forwards [9, 10].

In sports like wrestling and judo, there is categorization of players into different weight slots. Such categorizations require gain or loss of body weight wherein body composition analysis is applied to maintain healthy ratio of fat and fat free mass during such processes.

Apart from the field of physical fitness and sports, body composition analysis is also applied in the field of nutritional, anthropological, pediatric growth and maturation and other clinical and community research settings [11]. The parameter has been applied by many researchers to track advancements and improvements in disorders like AIDS, gastrointestinal malfunctions, Crohn disease and renal disorders [12-15].

There are different techniques available for body composition analysis. They all differ according to the complexity involved and suitability depending upon the study conditions. Still Cadaver Analysis is the only method to give accurate estimates of fat and fat free mass.

1.1 Indirect methods

1.1.1 Anthropometry

In this technique, various body measurements and skinfolds are taken using dedicated instruments. The measurements are then used to calculate body density which is applied to a formula suggested by Siri to calculate body fat percentage. The method is quick, simple and easily applicable for population studies including infants. The accuracy and precision depends upon the skills of the investigator and is also subject to error in obese people.

1.1.2 Body Mass Index (BMI)

This relative ratio of height and weight is considered as globally used index for assessment of nutritional status and disorders caused due to eating behaviors. It is applied to have an idea of body composition though its relation with the same is controversial.

1.1.3 Waist circumference

It is used as an indicator of central fatness rather than whole body composition and is also a predictor of high blood lipids and insulin resistance.

1.1.4 Bioelectrical Impedance Analysis (BIA)

In this method low frequency alternating current is passed through human body. The body being a conductor offers resistance to the flow of current. The measured resistance value is used to calculate impedance index (stature^2/resistance). The impedance index gives the value of total body water which is further used to predict fat free and fat mass of the body. The method being simple, quick and requiring less of skilled investigators has gained popularity in past few years.

However, the results are error prone depends upon precautions like emptying of bladder, food and beverage intake before assessment and it also unable to give correct fat content in obese individuals. Segmental analysis can be used to avoid such confounding effects [16].

1.2 Direct methods

1.2.1 Isotope dilution technique

In this method deuterium oxide dilution gives a measure of total body water. Total body water is exclusively found in fat free mass. So, an estimate of total body water can be used to predict fat free mass. However, it has limited applicability for obese as extracellular water level increases with obesity.

1.2.2 Total body counting and neutron activation

In this technique fat free mass is predicted by measuring amount of naturally radioactive potassium (K^{40}). Neutron activation technique has been found accurate for tissue specific body composition. In this method tissues are exposed to a neutron field and when the cell nucleus relaxes back to pre-exposed state, gamma output is detected. The method is used to measure concentration of elements like carbon, nitrogen, sodium, calcium etc which in turn gives body composition at molecular level.

1.3 Criterion methods

1.3.1 Densitometry

Body density is calculated through underwater weighing which is then converted into body fat using Siri's or Brozek's equation. The technique of underwater weighing relies upon subject performance and is subject to error. The method is also less practical to apply on children and obese for submerging them under water. Alternatively, air displacement plethysmography can be used.

1.3.2 Dual Energy X-ray Absorptiometry (DEXA)

It involves whole body scan through X-ray absorption. The method can comparatively give more accurate estimates of fat, lean and bone tissues separately. However inter-manufacture differences are found. Technique is more practical both from subject and operator's point of view.

***1.3.3 Computed tomography* (CT) *and Magnetic Resonance Imaging* (MRI)**

The techniques are very popular and are highly applicable for segmental body composition analysis. Whole body scan however is impractical as it incorporates high radiation exposure and is also very costly.

In past few decades, body composition analysis has grown as a popular area of research. Many studies have been conducted worldwide including indian population as well. Some studies are also there in which various methods have been compared among normal, diseased and athletic population [16-19]. Kamimura et al in 2003, tracked body composition changes in haemodialysis therapy and mentioned skinfolds as more preferable method over BIA [15]. Wattanapenpaiboon, Lukito, Strauss, Hage, Wahlavist and Stroud in 1998 compared DEXA, skinfold and BIA, where skinfold was found to have better agreement than BIA with DEXA results [20]. In another study conducted on non-obese and obese population, good agreement was found between anthropometry and BIA in former which decreased in latter [21].

When talking in Indian context, not much of the kind work has been conducted and athletic population has also been not much explored in the respective area of research. Kuriyan, Thomas and Kurpad in 2007 have worked upon predictive equations to assess muscle mass in healthy Indian males through BIA and anthropometry [22]. Nahar, Joshi and Kale in 2013 compared anthropometry and BIA as predictor of hypertension and found that both the methods comparable and BIA not a superior technique over anthropometry [23]. Also significant difference was found between the two methods by Chahar, 2013 [24].

Present study is based upon Indian athletes from Sports Authority of India, Jawahar Lal Nehru stadium to compare application of BIA and anthropometry as interchangeable methods for estimating fat mass and fat free mass of sportspersons. . As far as the mentioned population is concerned, no such research has been conducted in the past comparing the methods of BIA and anthropometry. Objective of the study is not only to compare the two methods but also to find which is the more feasible one out of the two as far as the field conditions are considered with players having busy schedule and in which the intra-group variation and chances of errors are less.
Limitation of the study lies in its small sample size due to strictly defined inclusion and exclusion criteria. Also, the accuracy of the values of variables obtained could have been established if both the methods could have been cross checked with the direct measurements.

However, the study is first of its kind as no such work has been done in the respective universe of study. The results obtained can be extrapolated in large samples for future validation and reproducibility. Using the same principles, other comparative studies can be conducted to come out with more feasible field techniques and methods.

2. Methods

2.1 Participants

After initial screening 83 players from various sports discipline at Sports Authority of India, Delhi were selected during precompetitive period. The inclusion criteria on the basis of which players were selected as the part of study included:

- Age group 18-25 years
- More than 2 years of training
- State or national level player

The players who couldn't meet the following exclusion criteria were not considered as part of the study:

- Players with metallic implants or prosthetics attached to body
- Players having less than 2 years of training
- Those who have not represented their game at state or national level competition
- The players who had large gaps between their training schedules due to any reason were also excluded

Procedure:

With the approval of the institutional review board of Sports Authority of India, the entire study was conducted for a period of six months including pilot study. All the participants were informed about the purpose, procedure, potential risks and benefits of the tests and an informed consent was taken from them. After that anthropometric measurements and BIA values were taken for each player. All the measurements of every player were taken in the morning hours and mandatory precautions were taken care of to avoid any technical error.

1) Anthropometric measurements

The participants wore light clothing and no footwear. Height was measured to the nearest 0.1cm and weight to the nearest 100 g using correctly calibrated SECA analystics digital stadiometer and weighing scale respectively. The landmarks for anthropometric measurement were located and marked. Four skinfolds biceps, triceps, subscapular and suprailiac were measured using Holtain skinfold caliper and the same were used to calculate body density using Durnin and Womersley's equation, 1974. The body density was further used to calculate body fat percentage using Siri's equation.

2) Bioelectrical Impedance Analysis

The participants were instructed a day before to come for the test fasting and with empty bladder with all metallic accessories, coins and mobile phones got removed from the body. Whole body bioelectrical impedance analysis was carried out on each subject through SECA body composition analysis under uniform and controlled laboratory conditions.

3) Statistical Analysis

All the measured variables and their values were entered into SPSS software and necessary calculations were performed. All the values were expressed as mean ± SD. Pearson correlation was used to see how much the value are related but agreement between the methods was assessed through Bland-Altman Plot.

2.2 Bland Altman Plot

It is a graphical statistical method used to estimate the limits of agreement between two methods wherein, the individual subject differences between body fat percentage values obtained by the two methods were plotted against the respective individual means. Limits of agreement were calculated as mean ±1.96× Std. Deviation. The method helps to avoid any statistical artifact especially when the true value of the variable is not known because of the absence of any gold standard method applied. The method gave an indication of systematic bias and random error evident by direction and magnitude of scatter around zero line respectively.

3. Result

The descriptive statistical of the parameters assessed is as follows:-

Table 1: Showing descriptive statistics.

		Fat% Anthropometry	Fat % BIA	Weight (Kg)	BMI	(Anthropometry-BIA) Fat %
N	Valid	83	83	83	83	83
	Missing	0	0	0	0	0
Mean		13.083327	14.785060	63.931807	21.994466	-1.701733
Std. Deviation		5.0056382	9.2966979	11.0160253	3.0963182	6.5373473

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2: Showing correlation between the two methods.

Correlations			
		ANTHROFAT	SECAFAT
ANTHROFAT	Pearson Correlation	1	0.739**
	Sig. (2-tailed)		0.000
	N	83	83
SECAFAT	Pearson Correlation	0.739**	1
	Sig. (2-tailed)	0.000	
	N	83	83

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson correlation value of 0.739, ($p \leq 0.05$) reflects internal consistency of the data and limits of agreement between the two methods was set with the help of the Bland-Altman plot obtained as follows:

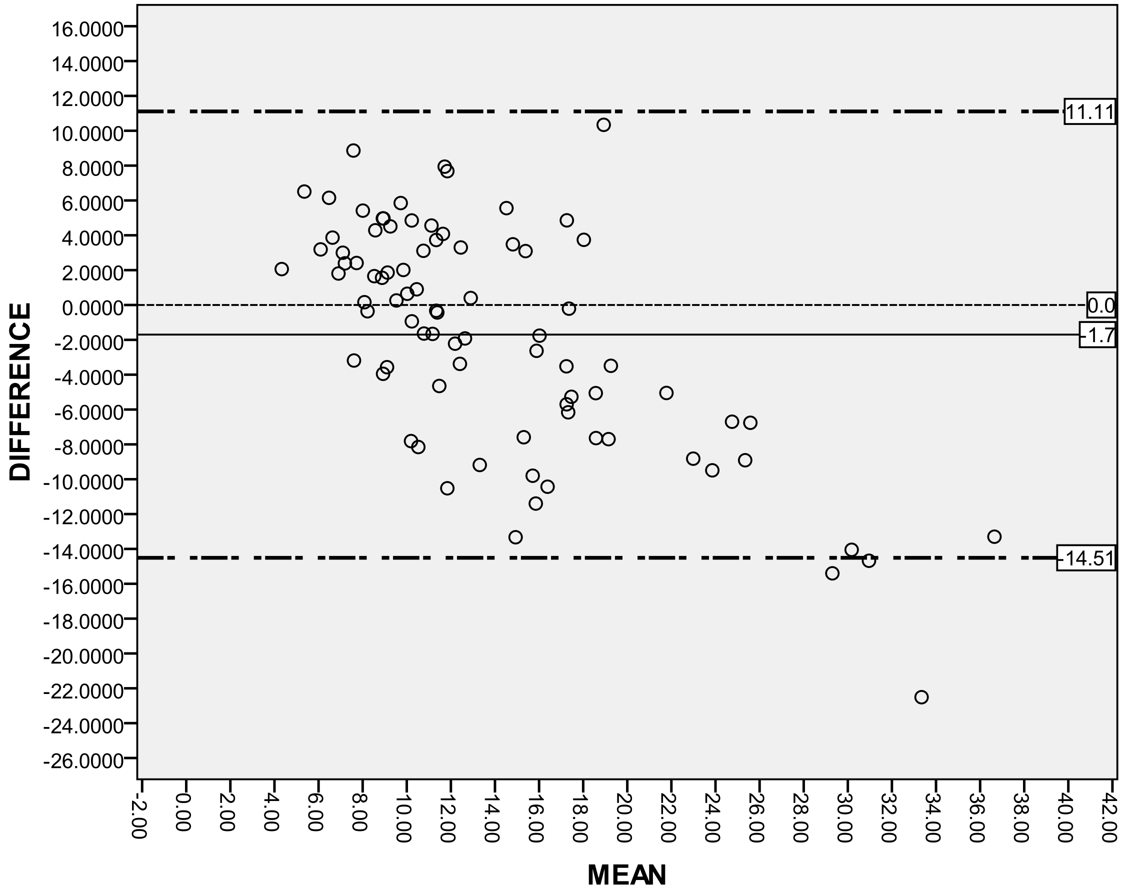

Figure 1: Bland- Altman plot showing limits of agreement between the two methods

The values plotted on Y-axis were obtained by subtracting body fat % obtained through BIA from the values obtained through anthropometry. As, there was no gold standard method to compare the two techniques, so mean of the individual body fat % of the two methods was taken as the most probable true value and the same was plotted on X-axis. The graph highlights four distinct lines. The solid line corresponding to value -1.7 shows mean difference which means BIA on an average always gives 1.7 % more value of fat than anthropometry. The dark and spaced dotted lines corresponding to values 11.11 and -14.51 represent limits of agreement between the two techniques which shows that anthropometric technique can give as more as 11.11 % and as less as -14.51 % body fat than BIA. This wide range of limits is clinically significant and focuses upon the fact that the two methods cannot be used interchangeably.

4. Discussion

A lot of research has been done on body composition analysis in many subsets of human population varying in terms of epidemiology, ethnicity and lifestyle patterns. It is the most basic and one of the primary parameters assessed in physical health and hospital settings to have an indirect track of metabolic changes occurring during illness, medications and fitness programs. The coaches, trainers and sports scientists track specific adaptations to training regimens of the athletes through body composition data.

Many direct, indirect and criterion techniques are there to assess body composition of people. While most of the direct and criterion methods are costly and inaccessible to large sectors of population, indirect and in vivo methods have wider applicability.

The study was conducted with an aim to apply anthropometry and BIA as interchangeable methods to assess body fat percentage of players depending upon the applicability of any technique during the prevalent circumstances at the time of assessment.

Anthropometry came into practice much earlier than BIA and has been into practice as a reliable method of body fat estimation if handled in a skilled manner. After BIA becoming popular to assess the same parameter, it becomes necessary to study whether the two methods can be used interchangeably or the latter can replace the former completely.

As evident from the results obtained from the present study large discrepancies have been reported between the two techniques as there is a wide gap between the limits of agreement. At times one method can give considerably high values and also very low values of body fat% at other times. The discrepancy can arise due to many reasons involved as both the techniques are sensitive to certain external and internal factors. However, during the entire study all the necessary measures and precautions were strictly taken into account to reduce bias to their minimum levels.

While talking about anthropometry, body fat% largely depends upon the technique of skinfold measurement. So, it was confirmed that the instruments used were properly calibrated and the measurements were taken with a great expertise.

BIA on the other hand is highly susceptible to hydration status of the participants. In case the player being assessed has come directly after exhaustive practice or hasn't emptied his bladder, both the situations can account for incorrect values of impedance and consequently of body composition too. Same problem can be encountered if the subject being assessed is overweight and has above than normal deposits of adipose tissue. It causes the body to retain fluid and give false impedance and body composition analysis results. Due to these reasons the players were asked to adhere to pre-measurement criteria involved for BIA.

The findings of the present study provided clinically significant values of confidence intervals calculated as mean ±1.96× standard deviation which clearly indicates that the two techniques can't be used interchangeably to assess body fat percentage of the players. As the study conducted has is not suggestive of using the two techniques interchangeably, it is necessary to find which method is more suitable to carry out further body fat estimation.

BIA has become a popular method of body composition assessment during past few years in sports, fitness and community health settings. Along with body fat percentage it also estimates parameters like lean mass, total body water (TBW) and extracellular water (ECW) which help in prognosis of patients. The results obtained are considered to be accurate, precise and less time consuming [25]. When compared to anthropometry, BIA generates result on the spot and is less invasive to the participants involved [26]. However, there has been continuously reported uncertainty regarding its validity [27, 28]. Also, the body composition values derived from BIA are based upon empirical equations referring to only few populations in the world whose normative data can't be used to study a different population.

Anthropometry has been known since ages to assess growth and nutritional status. The techniques involved are simple, non invasive, cost effective and applicable in large sized population studies [29]. However, an expertise in handling technique is required as inter- and intra-observer reliability and the difficulties in accurately measuring the thicknesses in obese individuals are the reported practical drawbacks.

When speaking specifically about body fat estimation of athletic population using one technique out of the two, anthropometry has been found to be more preferable as only factor altering the output is obesity which results in incorrect skinfold measurements. The population for which the body fat estimation is to be done is however athletic population which falls in normal BMI ranges and obesity is not an issue to carry out measurements.

There is much scope to conduct similar research in a much larger set of the athletic population and comparison with other more accurate techniques like DEXA, CT scan or MRI is also suggested.

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