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Comparative Analysis and Agreement of Body Fat Percentage Using Skinfold Thickness and Bioelectrical Impedance in Young College Students

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ABSTRACT

Background: Body fat analysis is an essential measurement for understanding adiposity in the population. There are several methods to assess adiposity, like anthropometric measurements, and recently, body impedance analysis has been used for the analysis of adiposity; thus, it is important to compare skinfold thickness (SFT) and bioelectrical impedance analysis (BIA) in measuring body fat percentage among young college students. **Methods:** Two methods were compared to analyse the adiposity among young college students i.e. SFT and BIA, both of which are non-invasive techniques and are used widely for assessing body fat. Accordingly, 145 students between the ages of 18-29 year were enrolled (41 males, 104 females) and their body parameters, and adiposity was measured using SFT and BIA. **Results:** The participants' mean BMI was 23.08±4.02 kg/m^2 for females and 23.63±3.80 kg/m^2 for males. According to SFT and BIA procedures, the female had a body fat percentage of 30.62±4.31% and 37.50±6.70%, respectively, while the male had a percentage of 20.06±5.12% and 24.78±8.73%, respectively. A positive correlation (*P*<0.001) was found between both assessment procedures. The Bland-Altman plot revealed a proportionate bias towards the body fat measurements between females (r=0.853, *P*<0.001) and males (r=0.496, *P*<0.07). It also demonstrated SFT and BIA approaches which were not in agreement with body fat percentages as BIA overestimates fat percentage when compared with skin fold thickness. **Conclusion:** The two approaches cannot be used interchangeably. However, for better understanding cut-off values can be changed according to the assessment method used to analyse adiposity.

Introduction

The health and wellness of any individual are greatly impacted by dietary intake and physical activity. Various nutritional assessment methods have been used in past, and researchers are continuously finding an effective method. Body composition measurement has been an opportunistic tool to assess the nutritional status and functional abilities quantitatively and assist in the formulation of a nutritional management plan (Brunani *et al.*, 2021). Overweight and obesity have been serious public health concerns, and the percentage of overweight people is shockingly growing. From health to performance, body fat percentage (% of body fat) plays an important role

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in physiological functions (Oukheda *et al.*, 2023). Studies have demonstrated a correlation between centrally distributed adipose tissue and insulin resistance, hypertension, dyslipidaemia, and impaired fasting glucose (Yun *et al.*, 2018). By measuring the body fat percentage of individuals early on, nutritional screening and assessment allow for timely intervention, and thus, help maintain the health and wellness of individuals and improve the quality of life. With increasing awareness about the health and wellness regime among individuals, professionals are looking for precise techniques for the evaluation of body composition (Holmes and Racette, 2021).

The transition from parental home to university life leads to numerous challenges among students, including the adaptation to unhealthy dietary lifestyles, limited access to local foods, insufficient knowledge, developed dietary habits, and the high cost associated with healthy food options (Yun *et al.*, 2018). During this period, different personal factors, including willingness, preferences, sensory perception, and several environmental or cultural factors, may inhibit university students from adhering to nutritional recommendations. Consequently, young students may transition from a normal weight status to overweight, thereby increasing their susceptibility to chronic diseases. The efforts to consume nutritious foods are frequently hindered by various perceived or experienced obstacles, including culinary customs, societal influences, personal habits, and limited access or higher costs associated with healthy food choices (Yun *et al.*, 2018).

Determining adiposity among college students is especially crucial because overweight and obesity are becoming more prevalent, which increases the risk of developing chronic diseases in adulthood. Although the Body Mass Index (BMI) is frequently used to categorize health status, its ability to accurately measure adiposity may be limited because it does not differentiate between lean and fat mass (Almoraie *et al.*, 2024).

Several methods have been developed to directly quantify body fat percentage in order to overcome this constraint. Bioelectrical impedance analysis (BIA) and skinfold thickness (SFT) measurements are two popular non-invasive techniques (Tornero-Aguilera *et al.*, 2022) . In order to evaluate body fat, skinfold thickness uses anthropometric measurements at a particular body site, while BIA uses electrical conductivity across human tissues to estimate body composition (Toselli, 2021). Despite their usefulness and accessibility, methodological variations frequently cause disparities among these tools.

Prior studies have examined the agreement and comparability of SFT and BIA in diverse populations; however, reported findings are not consistent because of variations in study design, sample demographics, and calibration techniques (Toselli, 2021). This emphasizes the need for further studies on how effectively these approaches work together, especially when it comes to young adult populations.

The present study aims to compare body fat percentage estimations using SFT and BIA among Indian college students, providing insight into the agreement and potential interchangeability of these techniques. This comparison will inform practitioners and researchers on the most appropriate, accurate, and practical methods for body fat assessment in this population.

Materials and Methods

Study participants

This cross-sectional observational study was conducted by convenience sampling from Sharda University students. Students from different streams and different years were invited to participate in the study. The students between the age group 18-29 both males and females were included in the study; however, the students with any hormonal imbalances, suffering from diabetes mellitus, hypertension, polycystic ovarian disease or any other illness were excluded from the study. A total of 147 participants were screened for the study and 2 individuals were excluded due to incompetence. Thus, the study was conducted on a total of 145 participants.

Procedure

The study was conducted in the University

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Grant Commission (UGC), India, and was approved by the Institutional Ethical Committee (IEC). The objective of the study was explained to the participants enrolled in the University for higher education and informed consent to participate in the study was obtained. This cross-sectional study was conducted between August 2024 and December 2024.

All the measurements were conducted in a fasting state in the morning hours, and participants refrained from eating or drinking anything for up to 7 hours before the measurements. Participants were also asked to avoid exercise for at least 12 hours before the data collection.

Measurements of anthropometry

The stature meter (Stature-meter04, Brand, MCP, India) was used to measure participants' height, to the nearest 0.1 cm. Participants were instructed to stand with their heads held in the Frankfurt plane with minimal or light clothing. A digital weight scale (NHD380W, Brand, Tanita, USA) was used to check the weight, and the results were categorized into different BMI categories (Chamarthi and Daley, 2025). The waist and hip circumferences were measured using a non-stretchable tape (tap11, Brand, SPAREQUE, India). The waist circumference was measured at the midpoint between the iliac crest and lower rib cage, while the hip circumference was measured at the level of maximum buttock extension. The waist to hip ratio (WHR) was computed (Silveira *et al.*, 2020, Yamashita *et al.*, 2012). Four locations were used to quantify SFT: the triceps, biceps, subscapular, and suprailiac areas (Lahole *et al.*, 2022). The skin pleated vernier calliper (Stainless steel professional Caliper, Brand, SKADIOO, India) was used to measure SFTs, and measurements were recorded to the closest 0.2 mm. The sum of skinfolds was then used to calculate the body density using the Durnin and Womersley equation (Silveira *et al.*, 2020). Body density was converted to body fat percentages (%) using Siri's formula (Aandstad *et al.*, 2014).

Impedance bioelectrical analysis

The bioelectrical impedance-based body composition analyser was used to assess the body fat percentage. The trunk, two arms, and two legs are represented as five-cylinder compartments in the model of the body, with fat acting as an insulator (Branco *et al.*, 2023). When a person steps on the TANITA monitor, a safe electric signal is sent from their feet to their arms, legs, and belly electrodes. The electrical signal also travels through water and encounters resistance or impedance when it comes into contact with fat. It was thought that each compartment's impedance is inversely related to its cross-sectional area and proportionate to its height. Impedance, another name for the resistance, was measured (Brunani *et al.*, 2021). Visceral fat, protein, mineral mass, muscle mass, waist-hip ratio, body fat percentage, total body water, and free fat mass were assessed.

Ethical considerations

The study received ethical approval from Sharda School of Medical Sciences, Sharda University, Medical Council of India, Greater Noida, India (Ref. No. SU/SMS&R/76-A/2024/203), and participants provided written informed consent. All of the information was kept confidential.

Data analysis

All the data were recorded in Microsoft Excel Word (MS Excel) and analysed using Statistical Package for the Social Sciences (SPSS) v. 22.0 (IBM Corp., Armonk, NY, USA). The linear connection between the variables was tested using Pearson's correlation. The Bland-Altman plot/analysis was used to compare the various body composition analysis (BCA) procedures. The mean and standard deviation are used to represent the biases and limitations of agreement in body fat percentages between those obtained from SFT and BIA. The relationship between the acquired body fat percentages and the factors that contributed to them (anthropometric measures and BIA values) was investigated using linear regression. All the data was analysed at a 95% level of significance.

Results

The anthropometric measurements of the study participants are shown in **Table 1**. In the female group (n=104), the mean height was 157.87 ± 6.85 cm, the mean weight was

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57.74 ± 11.82 kg, and the average BMI was 23.08 ± 4.04 kg/m². Male participants (n=41) had a higher range of height and weight, with a mean height of 170.66 ± 7.25 cm and a mean weight of 68.95 ± 12.34 kg, resulting in an average BMI of 23.63 ± 3.80 kg/m². Waist circumference was greater in males (80.00±13.24 cm) than in females (72.27 ± 9.95 cm), although hip circumference was similar between the genders. Skinfold thickness measurements at all assessed locations (triceps, biceps, subscapular, suprailiac) were higher in females, leading to a higher average SFT-derived body fat percentage (30.62 ± 4.31%) compared to males (20.06 ± 5.12%). BIA-derived data showed 37.50 ± 6.70% body fat in females and 24.78 ± 8.73% in males. As expected, total body water percentage and lean mass metrics (protein, mineral, muscle mass, fat-free mass) were higher in males, while visceral fat percentage was higher in females.

Comparison between SFT body fat% and BIA body fat percent

Table 2 shows a consistent trend of higher body fat estimates with BIA compared to SFT in both genders. In girls, the mean subcutaneous fat tissue body fat percentages ranged from 27.94% to 32.79%, while the BIA values ranged from 34.40% to 42.40%. For males, SFT readings varied from 17.00% to 21.48%, and BIA results ranged from 21.03% to 27.83%. BIA systematically overestimated body fat, with statistically significant differences in both genders. The correlation between the two methods was extremely high in females (r=0.993, *P*<0.001) and males (r=0.961, *P*<0.001), indicating that although both methods ranked individuals similarly, their absolute values were not interchangeable. The results show that BIA consistently reports higher body fat percentages than SFT in the studied cohort, with a more pronounced difference in females.

Bland-Altman plot to compare the body fat percentages assessment for participants using BIA and SFT techniques

Table 1. Mean±SD of anthropometric measures and body composition in participants.

Variables	Female	Male
Height (cm)	157.87±6.85	170.66± 7.25
Weight (kg)	57.74±11.82	68.95±12.34
BMI (kg/m2)	23.08±4.04	23.63±3.80
Waist circumference (cm)	72.27±9.95	80.00±13.24
Hip circumference (cm)	91.81± 8.00	93.95±7.60
Mid upper-arm circumference (cm)	23.50±2.80	26.40±2.93
Triceps skinfold (mm)	17.99±5.09	13.79±5.83
Bicep skinfold (mm)	16.35±5.41	14.17±6.06
Subscapular skinfold (mm)	16.21±4.97	14.46±5.81
Suprailiac skinfold (mm)	16.40±4.88	14.30±5.34
Sum of skinfolds (mm)	1.03± 0.01	1.05±0.01
Body fat percentage (%)	30.62±4.31	20.06±5.12
BIA measurements		
Body fat percentage (%)	37.50±6.70	24.78±8.73
Total body water (%)	25.98±3.97	37.55±5.27
Protein (kg)	6.94±1.07	10.17±1.44
Mineral (kg)	2.59±0.40	7.44±0.49
Body fat mass (kg)	22.20±7.82	17.77±8.62
Muscle mass (kg)	18.98±3.23	28.69±4.36
Waist-hip ratio	0.86±0.08	0.90±0.06
Visceral fat (%)	10.69±4.47	7.34±4.46
Fat-free mass (kg)	35.51±5.44	51.17±7.20

The Bland-Altman plot indicates a proportional bias (r=0.853, *P*<0.001) for females. The difference in agreement between the SFT and BIA methods was also observed to be significant (**Figure 1**). BIA overestimates body fat percentage with limits of agreement for females -1.921 to 10.621%. Bland-Altman plots were used to assess whether SFT and BIA agree on body fat percentage estimates for both men and women. The plot (**Figure 1**) showed a substantial proportional bias (r=0.853, *P*<0.001) among women, indicating that BIA values tend to be higher than SFT values as the mean body fat percentage increases. The limits of agreement ranged from -1.92% to 10.62%, which suggests that for most individuals, BIA

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measurements could differ from SFT-derived values by about 2% or more than 10%. Overall, the bias was toward higher BIA readings.

Table 2. Mean±SD comparison between SFT body fat% and BIA body fat % of the participants.

	SFT body fat %	BIA body fat %	Coefficient (r)	P-value
Female				
	28.30±3.25	34.4±0.70	0.993	0.001
	30.06±4.47	34.61±6.09		
	28.63±3.93	35.91±6.89		
	31.36±5.30	37.80±7.21		
	31.51±3.52	37.68±6.27		
	30.94±3.71	38.02±6.82		
	32.79±2.42	42.40±4.53		
	27.94±8.81	34.62±8.18		
	29.70±3.88	38.20±8.49		
Males				
	19.74±4.95	25.29±9.71	0.961	0.001
	21.48±5.37	22.07±11.56		
	20.82±4.83	25.44±5.26		
	19.20±3.11	25.35±8.27		
	21.46±4.50	27.83±5.50		
	17.00±4.40	21.03±4.02		
	17.07±8.07	25.62±12.23		

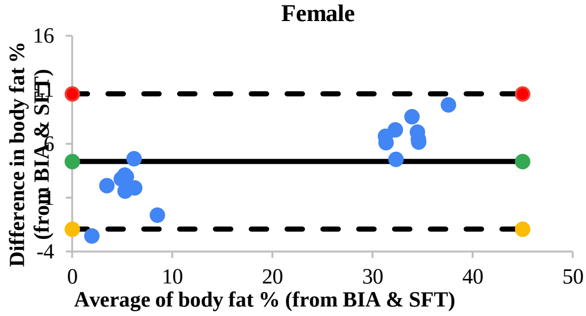

Figure 1. Graphical presentation of coefficient correlation between body fat percentage by SFT and BIA in females.

The Bland-Altman analysis (**Figure 2**) revealed a moderate proportionate bias in males (r=0.496, P=0.07), with limits of agreement between -1.15% and 9.32%. BIA also generally produced higher readings than SFT for men although this trend was less pronounced and not statistically significant. Collectively, these results indicate that BIA consistently overestimates body fat percentage compared to SFT in both genders, with a stronger bias in women. The relatively wide limits of agreement highlight the fact that these two methods should not be used interchangeably for individual assessments, especially in clinical or research contexts where accuracy is crucial.

Discussion

The present study assessed adiposity as a measure of obesity, transcending traditional measurements like BMI to offer a more precise evaluation of body composition. This study examined two prevalent methods in clinical and field practice: SFT assessed with calipers and body composition assessment by BIA. SFT provides simplicity, portability, and cost-efficiency, rendering it suitable for extensive and field studies (Almoraie *et al.*, 2024); however, it is susceptible to operator variability, inconsistencies in skinfold compression, discrepancies in site selection, and assumptions regarding uniform subcutaneous fat distribution. BIA assesses body composition by measuring the body's electrical resistance, which is affected by total body water and inversely related to body fat proportion (Silveira *et al.*, 2020). BIA is efficient, user-friendly, necessitates low operator expertise, and can yield supplementary metrics like hydration status, muscle mass, and visceral fat (Yamashita *et al.*, 2012).

Figure 2. Graphical presentation of the coefficient correlation between body fat percentage by SFT and BIA in males.

However, BIA consistently overestimated body fat in comparison to SFT, despite the findings which showed a substantial positive connection between SFT and BIA for assessing body fat percentage in both males and females. The findings align with previous research, including studies by Devi *et al* .and Thakur *et al*. (Devi *et al.*, 2019, Thakur *et al.*, 2022), which similarly indicated elevated %BF estimations from BIA in comparison to SFT or BMI, albeit robust correlations across the measures. Comparable trends have been observed across several populations, substantiating the perspective that while SFT and BIA are associated, they assess adiposity through distinct foundational principles (da Silva *et al.*, 2021). The results of the current study underscore that variables such as fat distribution, total fat volume, and the selection of skinfold sites can impact the accuracy of SFT measurements, whereas hydration status, body morphology, and device-specific algorithms might influence BIA readings. In the absence of gold-standard metrics such as dual-energy X-ray absorptiometry (DXA), both approaches are still viable alternatives, albeit necessitating meticulous interpretation (Wicherski *et al.*, 2021). The level of agreement between SFT and BIA may fluctuate according to demographic factors, BMI classification, and physical activity levels (Holmes and Racette, 2021, Toselli, 2021).

Recent studies have shown that although SFT, BIA, and DXA can provide generally similar group-level body fat estimates, more nuanced statistical evaluations, such as Bland–Altman plots and intraclass correlation coefficients, frequently uncover substantial discrepancies in agreement and reliability (Mecherques-Carini *et al.*, 2024, Nana *et al.*, 2015, Pietiläinen *et al.*, 2013). These findings, aligned with the results of this study, underscore the existence of method-specific bias, and indicate that these techniques should not be utilized interchangeably without proper calibration.

In conclusion, although both SFT and BIA are useful and accessible methods for measuring adiposity in environments devoid of advanced reference approaches, it is essential to recognise their strengths and limits. Operator competence, participant attributes, and method-specific biases can all affect outcomes. Identifying these parameters will enhance the precision of body composition evaluations in both research and clinical settings, facilitate the improvement of methods, and aid in the creation of more reliable measurement devices. A judicious and knowledgeable analysis of SFT and BIA outcomes will improve the formulation and targeting of strategies for obesity prevention and control.

The current study provides useful information on how well SFT and BIA methods work for measuring body fat percentage in young college students. This study only examined healthy young adults, but similar studies should be conducted on people of all ages, including those with other health problems or lifestyle-related disorders to gain a better understanding of how these assessment tools perform in different clinical and demographic settings. It is strongly recommended that future research employ gold-standard reference methods like dual-energy DXA to accurately evaluate the validity and potential systematic biases of both skinfold and BIA measurements. Having standardised measuring techniques and well-trained technicians-especially when using callipers-is crucial. This will help reduce operator-dependent variability and improve reliability. It is also essential to conduct subgroup analyses considering factors such as age, sex, BMI category, and health status, as the reliability and agreement of body fat assessment methods may vary across these groups. Ultimately, both SFT and BIA have advantages and disadvantages in field and clinical settings. Researchers and practitioners should carefully evaluate the strengths and weaknesses of each method and avoid using them interchangeably for individual clinical assessments without proper calibration. Following these recommendations will improve the accuracy of body composition analysis in future research and practice, leading to better nutritional and health evaluations across diverse populations.

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Authors' contributions

Shaida B and Rastogi involved in concept and study design. Data collection was done by Gupta M and Rastogi M. All authors involved in data analysis and interpretation, drafting the manuscript and all of them approved it for publishing.

Conflict of interest

There is not conflict of interest.

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