National Journal of Physiology, Pharmacy and Pharmacology

RESEARCH ARTICLE

Assessing body composition by bioelectric impedance analysis and dual-energy X-ray absorptiometry in physically active normal and overweight Indian males

Daisy Masih[1], Gurseen Rakhra[1], Annu Vats[1], Saroj Kumar Verma[1], Yogendra Kumar Sharma[2], Som Nath Singh[1]

[1]Nutrition Division, Defence Institute of Physiology and Allied Sciences, Delhi, India, [2]Biostatistics Division, Defence Institute of Physiology and Allied Sciences, Delhi, India

Correspondence to: Som Nath Singh, E-mail: nutrition-dipas@hotmail.com

Received: January 05, 2018; **Accepted:** January 31, 2018

ABSTRACT

Background: To improve body composition measurement methods for physically active healthy individuals, validation with of bioelectric impedance analysis (BIA) with using dual-energy X-ray absorptiometry (DXA) on basis of variation in body mass index (BMI) and physical activity are executed. **Aims and Objectives:** This study aimed to compare the single-frequency BIA with the more exact DXA so that a cost-effective instrument can be used for the research studies as well as by the general population. **Materials and Methods:** Thirty physically active male individuals were stratified on the basis of BMI as normal weight and overweight and also on the basis of the physical activity as low physical activity and high physical activity groups. The total body composition was analyzed using single-frequency BIA and by pencil-beam DXA scanner. **Results:** Fat-free mass (FFM) was significantly overestimated in whole sample as well as when the population was classified according to BMI and physical activity. Bland Altman's analysis stated agreement for fat mass (FM) with −0.06 kg proportional bias and −7.9 to +7.8 limits of agreement and for FM percentage (FM %) with −1.01% proportional bias and −11.1 to 8.9 limits of agreement while poor agreement was shown with FFM. BIA gives statistically similar values for FM and FM% in overall population in comparison to DXA. **Conclusion**: BIA can be preferred over DXA while conducting FM-based analysis on large populations.

KEY WORDS: Bland–Altman Analysis; Body Mass Index; Fat Mass; Fat-Free Mass; Fat Mass Percentage

INTRODUCTION

A precise evaluation of body composition variables is essential but simultaneously challenging for physically active individuals such as athletes, gymnasts, swimmers, and other sportspersons as every sport demands a different composition of fat mass (FM) and lean mass in the body. The body composition assessment fosters primitive detection of imbalanced FM and lean mass in body following which preventive measure can be taken to improve health and physical well-being. Increase in adiposity due to the deposition of fat in various regions of body refers to overweight and obesity according to body mass index (BMI).[1] The lack of irrefutable evidence concerning the distinction between the body fat percentage and lean body mass and the distribution of fat in body have made BMI, measure of adiposity, questionable. As promoted by public health counselors, a healthy diet and physical activity can put off the risk of overweight and obesity. Different types of exercises have a diverse impact on the body fat and fat-free mass (FFM) producing a different physiology

Access this article online	
Website: www.njppp.com	Quick Response code
DOI: 10.5455/njppp.2018.8.0100631012018	

and body composition.[2] There are several techniques to measure body composition including simple and direct as well as sophisticated and indirect measures. Among direct methods,[3,4] four-compartment model, air displacement plethysmography, and dual-energy X-ray absorptiometry (DXA) are included while indirect methods cover anthropometric measurements, skinfold measurement, body adiposity index, and bioelectric impedance analysis (BIA) to assess body composition.[3,5] Advanced techniques and methods are being developed to estimate body composition parameters accurately for research and clinical assessment. Consequently, new body composition assessment instruments need to be corroborated with more precise and sophisticated standardized instruments to make them more reliable.

Many promulgated research illustrated the comparisons between DXA and BIA for body composition.[6-12] Dual X-ray absorptiometry (DXA), a three-compartment model of body composition, i.e., FM, bone mineral content, and lean body weight[9] has been widely accepted as a standard technique for total body composition. DXA is an accurate and intricate method to compute total body composition with an advantage of a minimal error of measurement. However, it has a limitation of being expensive, tedious, and requirements of trained and dedicated facilities.[7] Thus, the need of an equivalent counterpart for accurate, however, expensive technique is always a constraint for large-scale studies. BIA, alternatively, is a simple, economical, non-invasive tool which considers same parameters such as FM, FM percentage, and FFM. A low electric signal of 50 KHz frequency passes from metal electrodes to body through body fluid and is resisted when some fat tissue blocks its path. BIA measures this opposition of body tissues to the flow of current in the body. BIA does not need any specialized trained individuals to operate it.

Body composition is influenced by exercise and the lifestyle one follows. Increased FM and body fat percentage leads to obesity, and increase in physical activity leads to increased muscle mass, and hence, FFM of the body. This study is important as limited literature is available on a comparison of BIA and DXA affirming effect of both obesity and physical activity in Indian population. The sample taken for the study belongs to the same ethnicity and is not diverse. A recent study on postmenopausal women by Gába *et al*. has also suggested undertaking more studies on BIA and DXA comparison with the basis of variation in BMI and physical activity for validation.[13] Validation of simple single-frequency BIA as an alternative method to DXA for the assessment of the body composition of general population who exercises regularly to maintain health is necessary. Thus, the purpose of the study was to verify the agreement of body composition analysis, i.e., fat mass (FM), percentage of fat mass (FM%), and fat free mass (FFM) between single-frequency BIA and DXA in individuals with different levels of obesity and physical activity.

MATERIALS AND METHODS

Subjects

The participants of the study were randomly selected from a fitness center situated in Karnal. The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all the participants before initiation of the study. The study protocol was elucidated to the individuals verbally as well as in written form. A total of 30 healthy individuals were recruited and stratified into 2 groups on the basis of their BMI, i.e., normal weight (BMI $\leq$24.9) and overweight/obese (BMI $\geq$25.0). Furthermore, on the basis of physical activity levels (PAL), the subjects were divided into 2 groups, i.e., low physical activity (LPA) (LPA, PAL $<$1.80) and high physical activity (HPA) (HPA, PAL $>$1.80).

PAL Value Assessment

Total energy expenditure (TEE) was measured using accelerometry-based actical system (Mini Mitter Co. Inc. Bend OR, USA). The actical devices were worn on wrist for 7 days, even during taking bath and swimming.[14] PAL value was calculated using the TEE and calculated basal metabolic rate (BMR) (PAL=TEE/BMR).

Anthropometric and Body Composition Measurements

The body composition analysis was performed early in the morning between 0700 h and 1000 h in post-absorptive state after overnight fasting. Height was measured by Seca rod to minimum 0.1 cm and body weight to the nearest 0.1 kg (Tanita BC-420MA Body Composition Analyzer, Tanita Corporation, Tokyo, Japan).

BIA

Subjects were asked to wear light clothing and to remove metallic items such as belt and rings from their body and stand on flat base bare feet on the body composition analyzer (Tanita BC-420MA).

DXA

Similar instructions were given to the subjects for DXA scan. The machine used for DXA scan was central pencil-beam scanner (GE Healthcare). The machine was calibrated daily using Spine Phantom block. The subjects were asked to lie in supine position in the center of the platform of the machine. The arm of DXA scanner scans the whole body by emitting X-rays. The total body composition was measured using DXA system (Lunar DPX-DXA System 14.10 Version, GE Healthcare, Madison, WI, USA) which took 15–20 min for one person. The images obtained were analyzed by the software.

Statistical Analysis

Statistical analysis was performed using SPSS Statistics Version 20.0 and Graph Pad Prism Version 5.01 software. Paired *t*-test was employed to compare the difference between the body composition values from two different techniques. All results were expressed as mean ± standard deviation (SD) and values having $P < 0.05$ were considered as statistically significant. To further evaluate the comparability and agreement between the two methods, we executed Bland–Altman's plot analysis[15] for FM, FM%, and FFM. The limits of agreement were determined as mean of differences ± 1.96 times of SD. Regression analysis was applied to verify the level of relative agreement between the different techniques.

RESULTS

The individuals recruited in the study had a mean age of 23.1 ± 4.6 years (range 18–30 years), height 172.9 ± 6.9 cm (range 161–192 cm), and weight 76.6 ± 14.7 (range 54.6–110 kg) with BMI of 25.4 ± 4.1 kg/m^2 (range 19.9–33.1 kg/m^2). The physical activity measured in terms of PAL value with minimum 1.06 to maximum 2.28. Table 1 exhibits the physical characteristics of the subjects. In the entire sample, lower estimation of FM and FM% and higher estimation of FFM was provided by BIA in comparison to DXA. The mean difference of FM was 0.1 kg ($P = 0.92$), FM% was 1.1% ($P = 0.25$), and FFM was 3.4 kg ($P = 0.0005$) in whole sample [Table 2]. In addition to the correlation graph, the Bland–Altman analysis plot with limits of agreement is shown in Figures 1 and 2.

Relative to normal weight group, overweight individuals had provided elevated FM, FM%, and FFM by both the techniques. Comprehensive data analysis states that in normal weight individuals, BIA provided significantly similar values for FM and FM%, i.e., 0.2 kg ($P = 0.74$) and 0.2% ($P = 0.85$), respectively, while FFM was significantly overestimated by 2.5 kg ($P = 0.01$) in contrast to DXA measurements, while in overweight group, FM and FM% were insignificantly underestimated by BIA by 0.5 kg ($P = 0.75$) and 2.0% ($P = 0.18$), respectively, while FFM was significantly overestimated by 4.3 kg ($P = 0.01$) in relation to DXA measurements. Table 2 depicts body composition parameters of entire sample, normal weight, and overweight participants based on BMI. Thus, in normal weight and overweight group individuals, BIA significantly overestimated FFM in comparison to DXA.

On evaluating the different activity groups, HPA group had significantly high levels of FM, FM%, and FFM in contrast to LPA group. Data analysis shows that BIA overestimated FFM by 3.0 kg ($P = 0.0009$) in LPA group while 4.1 kg ($P = 0.04$) in HPA group. On monitoring the FM and FM% of LPA and HPA group, no significant change in the measurements of DXA and BIA was observed. Table 3 presents body composition parameters of LPA and HPA based on physical activity. As a result, FFM was significantly overestimated in LPA and HPA group by BIA in relation to DXA.

Measurements of FM, FM%, and FFM acquired by BIA and DXA were significantly correlated (FM $r = 0.79$, FM% $r = 0.64$, and FFM $r = 0.71$, Figure 1). Figure 2 depicts the equation-based relative agreement between BIA and DXA with Bland–Altman's plot specifying the limits of agreements. The Bland–Altman's analysis was performed on DXA and BIA measurements considering the overall population. BIA produced variable results in comparison to DXA in terms of FM, FM%, and FFM. BIA underestimated FM with a mean difference between the methods as −0.06 ± 4.0 kg with 95% limits of agreement as −7.95–7.81. BIA also underestimated

Table 1: Characteristics of the subjects

Characteristics	Mean±SD	Range
n	30	-
Sex		
Male		-
Age (years)	23.1±4.6	18–30
Weight (kg)	76.6±14.7	54.6–90.9
Height (cm)	172.9±6.9	1.61–1.92
BMI (kg/m^2)	25.4±4.1	19.9–33.1
PAL	1.64±0.3	1.06–2.28

SD: Standard deviation, BMI: Body mass index, PAL: Physical activity levels

Table 2: Body composition parameters of entire sample, normal weight, and overweight participants based on BMI

Parameters	All (*n*=30)	Normal weight *n*=15	Overweight *n*=15
BMI (Kg/m^2)	25.4±4.1	22.2±1.8	29.1±2.9
FM (Kg)			
BIA	18.5±7.4	12.8±3.3	24.6±5.9#
DXA	18.6±8.7	12.6±5.6	25.1±7.1#
FM %			
BIA	23.3±5.3	19.2±3.7	27.8±3#
DXA	24.4±8.3	19.4±7.2	29.8±6.1#
FFM (Kg)			
BIA	58.0±7.7**	53.4±4.9*	62.9±7.7*#
DXA	54.6±8.6	50.9±3.7	58.6±10.9#

Values are represented as mean±SD. Paired *t*-test applied between measurements of DXA and BIA and unpaired *t*-test applied between normal weight group and overweight group. Values are significantly different from DXA measurements *P<0.01, **P<0.001, N.S.: Not significant, #values are significantly different from normal weight group P<0.001. BMI: Body mass index, FM: Fat mass, BIA: Bioelectric impedance analysis, DXA: Dual X-ray absorptiometry, FFM: Fat free mass

Table 3: Body composition parameters of LPA and HPA based on physical activity

Parameters	LPA *n*=17	HPA *n*=13
Weight (Kg)	69.9±10.8	79.5±23.8
BMI (Kg/m^2)	23.7±3.5	26.4±7.0
TEE (Kcal/d)	2481±442	3442±1046***
BMR (Kcal)	1658±156	1762±460**
PAL	1.49±0.2	1.84±0.5***
FM (Kg)		
BIA	15.2±5.9	21.8±8.0**
DXA	15.4±7.7	22.2±9.1*
FM %		
BIA	21.2±5.1	25.0±6.7**
DXA	22.2±8.1	26.9±8.9
FFM (Kg)		
BIA	54.5±5.7##	58.5±15.5#**
DXA	51.5±5.3	54.4±15.9*

Values are represented as mean±SD. Paired *t*-test applied between measurements of DXA and BIA and unpaired *t*-test applied between LPA group and HPA group. Values are significantly different (#*P*<0.05, ##*P*<0.0001, N.S.: Not significant) from DXA measurements. *Values are significantly different from LPA group **P*<0.05, ***P*<0.001, ****P*<0.0001. LPA: Low physical activity, HPA: High physical activity, BMI: Body mass index, TEE: Total energy expenditure, BMR: Basal metabolic rate, PAL: Physical activity levels, FM: Fat mass, BIA: Bioelectric impedance analysis, DXA: Dual X-ray absorptiometry, FFM: Fat-free mass, SD: Standard deviation

body fat percentage, i.e., FM% with a mean difference of −1.09 ± 5.1% with 95% limits of agreement as −11.1–8.9. BIA significantly overestimated FFM with a mean difference between the methods as 3.4 ± 4.7 kg and limits of agreement as −5.8–12.6. FM and FM% were inconsequentially underestimated by BIA; however, FFM was significantly overestimated. Consequently, the difference plot indicates FM and FM% measurements of BIA in agreement to DXA, while FFM measured by BIA showed disagreement to DXA.

DISCUSSION

Our study details total body composition analysis of 30 young, healthy active individuals from Karnal in terms of FM, FM%, and FFM when the individuals were classified on the basis of different levels of BMI and physical activity. The principle finding of the study is BIA significantly overestimated FFM in the overall study population as well as in the stratified groups, while statistically similar values for FM and FM% were observed in contrast to DXA in healthy young individuals.

Body weight gain in a population of a developing country like India has increased radically in the past few decades emerging as obesity and associated metabolic syndrome. While obesity reckons only body fat percentage, estimation of body composition becomes more imperative to refer this rampant disease. Nevertheless, there are always discrepancies in assessing FM, FM percentage, and FFM when determined by different techniques. Various researchers use varying techniques to establish prediction equations for body composition assessment using either single frequency (6, 8, 10, and 12) or multiple frequencies (3, 7, 9, and 11). The present study discusses the accuracy of body composition parameters by BIA considering DXA as a reference method. Detailed analysis showed that BIA measurements deviate from DXA measurements in all subgroups as well as in entire sample in terms of FFM with minimal deviation in FM and FM%. Bland–Altman analysis depicted large individual variation with wide limits of agreement for FFM. Nevertheless, FM and FM% showed small individual variation and percentage bias with wide limits of agreement advising about the errors in the evaluation of FFM by BIA in healthy physically active individuals. Contrary to our study, Wu *et al*. reported for a range of 20–30% body fat, FFM estimates are valid measurements in healthy Asian population by BIA[16] and in a weight loss program, Chinese researchers suggested that BIA presents comparatively precise prediction of % BF in individuals with normal, overweight, and obese weight.[17] Since there is proved relationship between fat percentage and BMI,[18] the present study classifies the individuals on the basis of BMI in two groups as normal weight and overweight. A comparison of our findings with those of earlier studies shows that FM, FM%, and FFM of overweight group were notably elevated in respect to normal weight individuals as also depicted by Völgyi *et al*.[12] The possible reason for the increased FFM in overweight individuals might be their increased body weight. Of comparisons, overestimation of FFM by BIA in all the subgroups as well as in the whole sample was significant, while similar values were observed in FM and FM% when the estimation of DXA and BIA were compared. These data were consistent with the data reported by Verney *et al*.[11] and Dehghan and Merchant[19] who reported no significant difference between DXA and BIA measurements of FM% while suggesting BIA as an accurate measure of body fat in a group of individuals who belong to the same ethnicity and are not diversified. In addition to BMI, the effect of physical activity was also analyzed on BIA accuracy. It is generally promulgated that for individuals with the same BMI, physical activity decreases FM%.[20] However, the present study indicates a significant increase of FM, FM%, and FFM in HPA group relative to LPA group when participants were allocated on the basis of PAL. The possible reason to this may be the excessive dietary intake of fat in individuals which increases their body weight, and hence, BMI in HPA group in comparison to LPA group due to which their FM and FM% are increased accordingly. Furthermore, higher FM may be required to support high muscle mass so as to expend a considerable amount of energy in carrying out extensive work. Our results established that there was a significant bias of 3.0 kg (P = 0.0009) and 4.1 kg

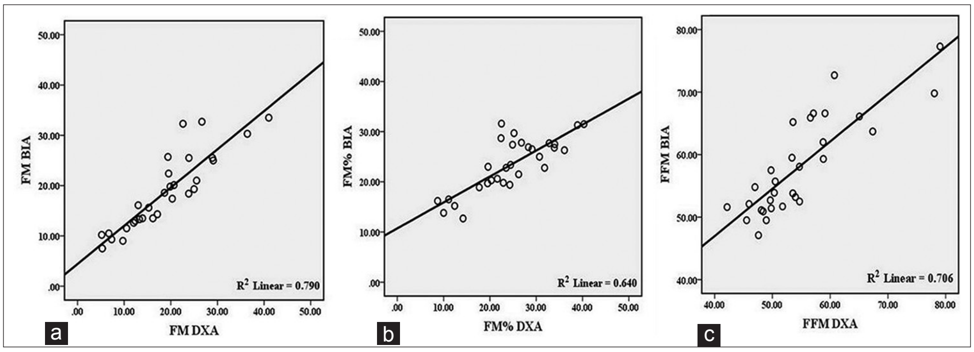

Figure 1: (a-c) Pearson's correlation between measurements of fat mass (FM), FM % and fat-free mass obtained by dual X-ray absorptiometry and bioelectric impedance analysis

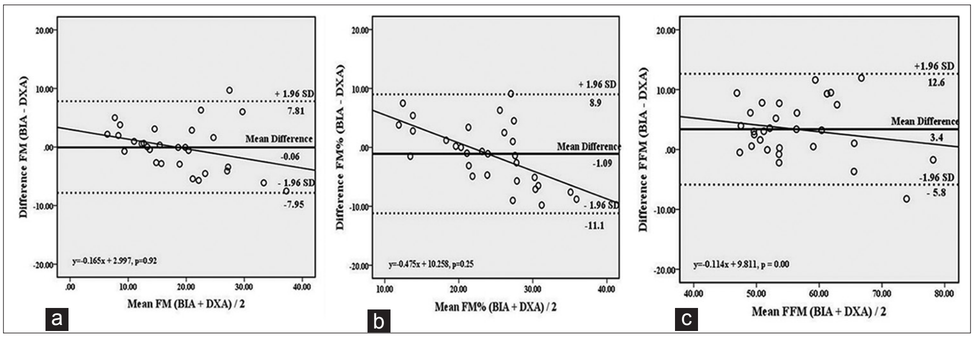

Figure 2: (a-c) Bland–Altman's plot showing 95% limits of agreement with mean difference between dual X-ray absorptiometry and bioelectric impedance analysis

(P = 0.04) for FFM in LPA and HPA group, respectively, while insignificant bias in FM and FM% was observed in the respective groups on comparing BIA and DXA values. A similar research was published by Gába *et al*. who worked on postmenopausal women and published similar results on physical activity as our study.[13] Many studies performed on women and men reported agreement and disagreement between DXA and BIA, but limited numbers of studies are reported on the men with different levels of obesity[6,10,12] and physical activity.[11,12] The linear relationship evaluated by Pearson's correlation showed that BIA is significantly correlated to DXA. Despite having a good correlation, comparing the difference plot of FM and FM% with earlier studies, a significant underestimation of FM and FM% by BIA is obtained in relation to DXA;[3,7,9,10,12] however, our study suggests a insignificant underestimation of FM and FM%. Since the more accurate isotopic dilution method for fat determination is not used for measuring hydration levels, it may be one of the possible reasons that significant overestimation of FFM and insignificant underestimation of FM and FM% are obtained in this study. In some studies, the entire sample provides the bias of FM ranged from minimum 0.9 kg[7] to maximum 3.1 kg[6] with wide limits of agreement.[6,7,10] Similar studies also discussed about underestimation of FM% in body ranging from 1.0%[10] to 6.3%[6] with wide limits of agreement from −20.1% to 11.4%.[6,7,9,10,12] A study on healthy young adults reported convergent result which stated the statistically insignificant difference between FM% measurements by DXA and BIA.[11] Furthermore, a significant overestimation of FFM with minimum 2.5 kg in normal weight group and maximum 4.3 kg in overweight group was observed. In overall population, 3.4 kg of overestimation of FFM by BIA in comparison to DXA was observed. Likewise, a cross-sectional study favors low agreement between BIA and DXA for assessing muscle mass.[21] The Bland–Altman analysis plot shows poor agreement in BIA and DXA for measurements of FFM with wide limits of agreement (−5.8–12.6). Published literature shows overestimation of FFM with mean difference ranging from −4.0 kg to 5.7 with limits of agreement −10.3 to 10.4.[6,7,9,10] Conversely, other studies showed insignificant difference between the measurements of BIA and DXA for FFM,[11] while a Mexican study found that hand-to-foot BIA was a better measure for FFM prediction and showed good agreement with DXA in young women.[22]

Strength and Limitation

The type of population on which study is conducted is of prime importance. The comparison between BIA and DEXA has been done on children and adolescents[23] or adults in middle age[9] in earlier studies from India. In the present study, the young Indian adults of average age 23 years are taken as subjects and have different levels of obesity and physical activity which strengthens our findings. The only limitation of the study is the smaller sample size. Although the instrument used for BIA shows comparable results for FM and FM%, the equation and algorithms on which the instrument calculates body composition parameters are based on the research studies of specific population which may be one reason of deviation of BIA accuracy from DXA.

CONCLUSION

The data from our study show that despite giving high mean prediction error for FFM, BIA can be used in place of DXA as it gives proximate prediction for body FM and FM percentage. As nutritional surveys also prominently require the estimation of body FM, the current study suggests that BIA can be preferred over DXA while conducting FM-based analysis on large populations where chances of error can be minimized. On the other hand, for general population who weighs body to maintain routine fitness, BIA can be a good, cost-effective and easily accessible equipment to be procure at their home or work places.

ACKNOWLEDGMENTS

Authors are thankful to the Director, DIPAS for all support and encouragement to this study. We acknowledge Mr. Sandeep Sharma for providing us subjects from his fitness center named The World Fitness Zone, Karnal, and Dr. Yogesh Chabbra for providing DXA scanner. DM is also thankful to DST for providing DST-INSPIRE fellowship.

REFERENCES

1. Sikaris KA. The clinical biochemistry of obesity. Clin Biochem Rev 2004;25:165-81.
2. Drenowatz C, Hand GA, Sagner M, Shook RP, Burgess S, Blair SN, *et al.* The prospective association between different types of exercise and body composition. Med Sci Sports Exerc 2015;47:2535-41.
3. Kuriyan R, Thomas T, Ashok S, Jayakumar J, Kurpad AV. A 4-compartment model based validation of air displacement plethysmography, dual energy X-ray absorptiometry, skinfold technique & bio-electrical impedance for measuring body fat in indian adults. Indian J Med Res 2014;139:700-7.
4. LaForgia J, Dollman J, Dale MJ, Withers RT, Hill AM. Validation of DXA body composition estimates in obese men and women. Obesity (Silver Spring) 2009;17:821-6.
5. Ramírez-Vélez R, Correa-Bautista JE, González-Ruíz K, Vivas A, García-Hermoso A, Triana-Reina HR, *et al.* Predictive validity of the body adiposity index in overweight and obese adults using dual-energy X-ray absorptiometry. Nutrients 2016;8:pii: E737.
6. Braulio VB, Furtado VC, Silveira Md, Fonseca MH, Oliveira JE. Comparison of body composition methods in overweight and obese Brazilian women. Arq Bras Endocrinol Metabol 2010;54:398-405.
7. Leahy S, O'Neill C, Sohun R, Jakeman P. A comparison of dual energy X-ray absorptiometry and bioelectrical impedance analysis to measure total and segmental body composition in healthy young adults. Eur J Appl Physiol 2012;112:589-95.
8. Moon JR, Stout JR, Smith-Ryan AE, Kendall KL, Fukuda DH, Cramer JT, *et al.* Tracking fat-free mass changes in elderly men and women using single-frequency bioimpedance and dual-energy X-ray absorptiometry: A four-compartment model comparison. Eur J Clin Nutr 2013;67 Suppl 1:S40-6.
9. Nigam P, Misra A, Colles SL. Comparison of DEXA-derived body fat measurement to two race-specific bioelectrical impedance equations in healthy indians. Diabetes Metab Syndr 2013;7:72-7.
10. Pateyjohns IR, Brinkworth GD, Buckley JD, Noakes M, Clifton PM. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity (Silver Spring) 2006;14:2064-70.
11. Verney J, Schwartz C, Amiche S, Pereira B, Thivel D. Comparisons of a multi-frequency bioelectrical impedance analysis to the dual-energy X-ray absorptiometry scan in healthy young adults depending on their physical activity level. J Hum Kinet 2015;47:73-80.
12. Völgyi E, Tylavsky FA, Lyytikäinen A, Suominen H, Alén M, Cheng S, *et al.* Assessing body composition with DXA and bioimpedance: Effects of obesity, physical activity, and age. Obesity (Silver Spring) 2008;16:700-5.
13. Gába A, Kapuš O, Cuberek R, Botek M. Comparison of multi- and single-frequency bioelectrical impedance analysis with dual-energy X-ray absorptiometry for assessment of body composition in post-menopausal women: Effects of body mass index and accelerometer-determined physical activity. J Hum Nutr Diet 2015;28:390-400.
14. Singh SN, Vats P, Shukla V, K. A. A comparison of free living energy expenditure determinations of physically active Indians using different methods and the validation against doubly labeled water. In: Bhaskaran M, editor. Non-Nuclear Applications of Heavy Water and Dueterium. New Delhi: Macmillan Publisher Indian Ltd, Delhi; 2010. p. 194-204.
15. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10.
16. Wu CS, Chen YY, Chuang CL, Chiang LM, Dwyer GB, Hsu YL, *et al.* Predicting body composition using foot-to-foot bioelectrical impedance analysis in healthy asian individuals. Nutr J 2015;14:52.
17. Li YC, Li CI, Lin WY, Liu CS, Hsu HS, Lee CC, *et al.* Percentage of body fat assessment using bioelectrical impedance analysis and dual-energy X-ray absorptiometry in a weight loss program for obese or overweight Chinese adults. PLoS One 2013;8:e58272.
18. Bindiya S, Gowda KM, Ashwini K, Roshima PM. Comparison of fat percentage with muscle strength/endurance and blood pressure response in young adults. Natl J Physiol Pharm Pharmacol 2017;7:4.
19. Dehghan M, Merchant AT. Is bioelectrical impedance accurate for use in large epidemiological studies? Nutr J 2008;7:26s.
20. Bradbury KE, Guo W, Cairns BJ, Armstrong ME, Key TJ. Association between physical activity and body fat percentage, with adjustment for BMI: A large cross-sectional analysis of UK Biobank. BMJ Open 2017;7:e011843.
21. Buckinx F, Reginster JY, Dardenne N, Croisiser JL, Kaux JF,

Beaudart C, *et al*. Concordance between muscle mass assessed by bioelectrical impedance analysis and by dual energy X-ray absorptiometry: A cross-sectional study. BMC Musculoskelet Disord 2015;16:60.
22. Velazquez-Alva Mdel C, Irigoyen-Camacho ME, Huerta-Huerta R, Delgadillo-Velazquez J. A comparison of dual energy x-ray absorptiometry and two bioelectrical impedance analyzers to measure body fat percentage and fat-free mass index in a group of Mexican young women. Nutr Hosp 2014;29:1038-46.
23. Chiplonkar S, Kajale N, Ekbote V, Mandlik R, Parthasarathy L, Khadilkar V, *et al*. Validation of bioelectric impedance analysis against dual-energy X-Ray absorptiometry for assessment of body composition in Indian Children Aged 5 to 18 years. Indian Pediatr 2017;54:919-24.

How to cite this article: Masih D, Rakhra G, Vats A, Verma SK, Sharma YK, Singh SN. Assessing body composition by bioelectric impedance analysis and dual-energy X-ray absorptiometry in physically active normal and overweight Indian males. Natl J Physiol Pharm Pharmacol 2018;8(5):755-761.

Source of Support: This study was supported by Defence Research and Development Organization, **Conflict of Interest:** None declared.