Differentiation of body fat composition between skinfold caliper (SKF) and bioelectrical impedance analysis (BIA) methods among professors

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ABSTRACT

Body fat composition reflected by body fat percentage (BF%) is one of the important components in disease risk evaluation. Among the methods available to measure BF%, skinfold calipers (SKF) and bioelectrical impedance analysis (BIA) are the most commonly used. The study was conducted to evaluate the difference in body fat composition measurement between SKF and BIA methods among professors. This study analyzed secondary data from the health evaluation of Universitas Padjadjaran (UNPAD) professors. This study involved 72 professors (50 male, 22 female) after fitted into the inclusion and exclusion criteria. BF% was measured among UNPAD professors using SKF and BIA. After obtaining agreement by Bland-Altman Plot, the data were analyzed by muliple paired-t test according to gender, physical activity level and body mass index (BMI) categories. The study showed no significant difference in BF% between SKF and BIA in overall population, between gender and physical activity level ($p>0.05$). For BMI, the only category that showed significant difference in BF% between the 2 methods was obese I group ($p=0.001$). In conclusion, there is no significant difference in BF% between SKF and BIA methods according to gender, physical activity levels and BMI categories except for obese I group.

ABSTRAK

Komposisi lemak tubuh yang tercermin oleh persentase lemak tubuh adalah salah satu komponen penting dalam evaluasi risiko suatu penyakit. Di antara metode yang tersedia untuk mengukur persentase lemak tubuh, *skinfold caliper* (SKF) dan *bioelectrical impedance analysis* (BIA) merupakan metode yang paling umum digunakan. Penelitian ini dilakukan untuk membandingkan metode SKF dan BIA dalam pengukuran komposisi lemak tubuh pada guru besar (GB). Penelitian ini menggunakan data sekunder pemeriksaan kesehatan GB Universitas Padjadjaran (UNPAD), Bandung. Penelitian melibatkan 72 orang GB (50 laki-laki, 22 perempuan) yang memenuhi kriteria inkulsi dan eksklusi. Persentase lemak tubuh diukur dengan menggunakan metode SKF dan BIA. Setelah uji kesepakatan *Bland-Altman Plot*, data yang dianalisis oleh beberapa uji t berpasangan berdasarkan jenis kelamin, tingkat aktivitas fisik dan kategori indeks massa tubuh (IMT). Penelitian menunjukkan tidak ada perbedaan yang signifikan dalam persentase lemak tubuh pada populasi secara keseluruhan, berdasarkan jenis kelamin dan tingkat aktivitas fisik ($p>0.05$). Untuk IMT, satu-satunya kategori yang menunjukkan perbedaan yang signifikan pada persentase lemak tubuh antara 2 metode adalah kelompok obese I ($p=0.001$). Dapat disimpulkan tidak terdapat perbedaan signifikan pada persentase lemak tubuh antara metode SKF dan BIA berdasarkan jenis kelamin, tingkat aktivitas fisik dan kategori IMT kecuali pada kelompok obese I.

***Keywords*:** bioelectrical impedance analysis - body fat percentage – professors - skinfold caliper – body mass index

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INTRODUCTION

Body fat composition that reflected by body fat percentage (BF%) is one of the important components in disease risk evaluation, especially regarding to the influence of excess body fat and its distribution on the onset of non-communicable chronic diseases.[1] Assessment of body fat is still the prime focus of attention because it can give valuable information but its accurate measurement is difficult.[1,2] For precise evaluation, several methods are available which give a reasonably accurate measure of body fat composition, the most commonly and widely used methods due to their ease and feasibility are skinfold caliper (SKF) method and bioelectrical impedance analysis (BIA) method.[3,4]

Skinfold thickness is determined by pinching a fold of skin at the site and its thickness is measured using precision thickness calipers to represent the average thickness of the entire subcutaneous adipose tissue. Data from the sites of measurement will be used to analyzed by using specific formula to show the BF%.[5] While BIA is a portable non-invasive method that introduces a passage of low-level current into the body and measure the impedance to the flow. After identifying the levels of resistance to the electrical current, the calculation from the difference in conductivity can yield fat mass and lean body mass.[4,6]Body fat percentage can give a significant variation not only across age, sex and ethnic groups but also the occupation of an individual. Different occupations result in different body shapes and body composition because of the various physical activities required for each job. Among the groups that tend to have high BF% is the group that from the academic field with limited physical activity. This is supported by a previous research that find the prevalence of hypertension among medical lecturers in a university where the results show that more than 80% of them are either overweight or obese.[7] Regarding to this, the health of professors is the main issue of concern because they have many contributions to the society and the university as well. Because of their important role, professors require good health and body fitness to maintain their productivity. One of the factors that determine physical fitness is the BF%. This study was conducted to observe the difference in BF% between skinfold caliper and bioelectrical impedance analysis methods among professors based on gender, physical activity level, body mass index (BMI) categories.

MATERIALS AND METHODS

Subjects

The research was conducted by analytical comparative method using the cross sectional study design to compare the body fat composition of professors from Universitas Padjadjaran, (UNPAD) Bandung, Indonesia measured by SKF and BIA methods. The research was carried out at the Technical Service Unit of Health UNPAD from September to December 2016. The data were secondary data obtained retrospectively from the primary data of the previous research of UNPAD professors. Before the study proceeded, an ethical clearance letter with number 1022/UN6. C1.3.2/KEPK/PN/2016 was obtained from the Ethical Clearance Committee of Faculty of Medicine, UNPAD Bandung. Samples were collected using consecutive sampling technique. The inclusion criteria included active UNPAD professors that are still teaching including the emeritus professors with complete data needed consisting of sex, BMI and physical activity level. The subjects with very extreme body fat percentage results compared to the others were excluded.

Protocol of study

Skinfolds were measured with a Lange SKF caliper by different enumerators at 4 anatomical sites: triceps, suprailiac, abdomen, and thigh. All skinfolds were measured to the nearest 0.5 mm on the right side of the body. Each site was measured 3 times with the mean recorded for analysis. Measurements were taken following the

recommended standardization procedures from the Anthropometry Standardization Reference Manual.[5] The BF% was then calculated by substituting the respective skinfold values into the Jackson and Pollock's generalized body composition '4-sites formula' according to male and female.[8] The equations were as follow :

BF% (male) = 0.29288 (X) – 0.0005 $(X)^2$ + 0.15845 (Y) – 5.76377 (X)

BF% (female) = 0.29669 (X) – 0.00043 $(X)^2$ + 0.02963 (Y) – 1.4072 (X)

Note: X = Sum of four skinfolds (in mm)
Y = Age (years)

BIA was performed with subjects in standing position with both feet shoulder-width apart using OMRON BIA analyzer HBF-306. Before the measurement, the data including sex, age, height and weight were inputted manually into the analyzer. Then the grip electrodes were held by both hands of the subjects and a 50kHz electric current passed from one hand to the other. The resistance value was measured. Body fat percentage that estimated by the prediction equations supplied by the manufacturers equation, was digitally displayed and recorded.

Statistical analysis

The distribution of the data collected was tested using Kolmogorov-Smirnov normality test ($z>0.05$). Agreement between methods was compared using Bland-Altman plot and the limits of agreement were estimated as the mean inter-method differences ± 1.96 SD. Multiple paired t-test were done to compare the BF% obtained from the 2 methods according the gender, physical activity level and BMI categories. Statistically significant result was considered when $p < 0.05$.

RESULTS

TABLE 1 shows the characteristics of UNPAD professors according to gender, physical activity level and BMI categories while TABLE 2 shows the mean value of each characteristics. From the results, UNPAD professors were dominated more by male than female. The mean age of the professors was 72.9 ± 9.2 years. As much as 44% of the professors were aged 65-74 years old. The mean value for the BMI was 26.0 ± 4.4 kg/m^2, that falls into the category of obese I according to the WHO Asian classification of BMI. There were 33 inactive professors (45.8%) who did not meet the recommendations of the WHO GPAQ and 39 active professors (54.2%) who meet the recommendations. For the BF% derived from skinfold caliper and BIA methods, the mean value were similar, 26.56 ± 5.70 % and 26.62 ± 6.65 % respectively (TABLE 2).

TABLE 1. Characteristics of UNPAD professors

Characteristic	Frequency (n=72)	%
Age		
• 45-54	2	2.8
• 55-64	9	12.5
• 65-74	32	44.4
• 75-84	27	37.5
• 85-94	1	1.4
• >94	1	1.4
Gender		
• Male	50	69.4
• Female	22	30.6
BMI		
• Underweight	3	4.2
• Normal	11	15.3
• Preobese	15	20.8
• Obese I	33	45.8
• Obese II	10	13.9
Physical activity level		
• Inactive	33	45.8
• Active	39	54.2

TABLE 2. Mean value of characteristics of UNPAD professors

Characteristics	Mean ± SD
Age (years)	72.90 ± 9.2
BMI (kg/m^2)	26.00 ± 4.4
SK BF (%)	26.56 ± 5.70
BIA BF (%)	26.62 ± 6.65

In the Kolmogorov-Smirnov normality test, the p-value obtained for the BF% from SKF and BIA method were both 0.200. It can be concluded that the distribution of the BF% from the methods was normal because p>0.05. As the data is normally distributed, Bland-Altman Plot was used to assess the comparability between the methods. Results suggested great agreement between the two methods by yielding a narrow limits of agreement.

Then, paired t-test was used to calculate the p-value to compare the mean BF% obtained from the two methods. Results showed that there was no significant difference between the BF% obtained from both SKF and BIA methods in the population as a whole with the difference 0.06 ± 4.66% , (p = 0.05).

TABLE 3. Results from paired t-test to compare BF% between SKF and BIA

Characteristic	p	Mean difference (%)
Gender		
• Male	0.338	-0.09 ± 0.67
• Female	0.999	-0.03 ± 8.51
Physical activity level		
• Inactive	0.987	0.14 ± 4.96
• Active	0.855	-0.13 ± 4.45
BMI		
• Underweight	0.432	-0.86 ± 1.52
• Normal	0.090	-0.70 ± 1.24
• Preobese	0.705	0.71 ± 7.09
• Obese I	0.001*	-0.80 ± 1.22
• Obese II	0.459	2.14 ± 8.74

*p-value is significant, p < 0.05

Multiple paired t-test were then conducted to evaluate the mean difference in the BF% measured by SKF and BIA methods based on gender, physical activity level and BMI categories. Between genders, the p-values for the BF% measured by SKF and BIA methods were 0.338 and 0.999 respectively (p>0.05). It can be concluded that there was no significant difference in the BF% measured by both SKF and BIA methods between male and female groups.

When analyzed by physical activity level, similar results were exhibited in the BF% measured by the two method between active and inactive groups (p>0.05), showing there was no significant difference. For the BMI, the only category that showed significant difference in BF% between the 2 methods is obese I group (p=0.001) where SKF measured higher BF% in obese I professors than BIA method while the other categories showed no significant difference.

DISCUSSION

Fifty percent of the UNPAD professors from the research fall into the obese I and II categories and relatively they have higher BF% measured by both skinfold caliper and BIA methods. In terms of age, there is more than 50% of the professors aged 60 years old and above and they belong to the 'elderly' group according to Law of Republic Indonesia No. 13 year 1998 on Older Persons Welfare where elderly refers to a person who is aged 60 years old and above.[9] From the results, most of the comparisons do not show significant differences between SKF and BIA methods as suggested in the hypothesis. The only significant difference found in the BF% between the 2 methods is the obese I group. The difference can be explained by the gender differences, aging process, difference in skinfold compressibility, difference in the skills of measuring technicians, hydration status and physical activity before measurement.

A study was conducted in military men to compare their BF% using SKF, BIA and

ultrasound (US) and the results showed that there was no significant difference between SKF and BIA in relation to US.[10] While another previous research showed that there was no statistically difference in the mean BF% estimated by between SKF and BIA in the population of physically active athletes, that is similar with the result of this present study.[2] From the data, UNPAD Professors are dominated by male. The fat distribution between male and female is different and this may contributes to the difference in the BF% measured by SKF and BIA. Compared to male, female have more adipose tissue and mainly it is stored subcutaneously before menopause. After menopause, female are prone to display a more android fat distribution. In this study, female professors mostly are in post-menopausal stage where there is an increase in total body fat mass due to the decreased estrogen level as estrogen plays an important role in regulating body fat distribution in women.[11,12]

Besides, aging process is another possible factor that responsible to the difference in the results. Aging is associated with its inherent changes in body composition may induce errors in estimations in BF%. Fat-free mass (FFM) progressively decreases, whereas fat mass increases along with aging. Aging is also related with a redistribution of both body fat and FFM with a greater relative increase in intraabdominal fat than in subcutaneous or total body fat.[13] Therefore, the BF% obtained from SKF might not be the precise value of the body fat content of professors because the use of the SKF depends on the assumption that the skin thickness may represent a constant proportion of total body fat.[11]

Moreover, skinfold thicknesses are influenced by the compressibility of subcutaneous that differs by age and sex. The measurement error of skinfold may be increased by the inter-individual differences in skinfold compressibility.[11]The difference in the results maybe also be the result of the fact that females have less compressible SKF than males and compression of the fat layer during the use of calipers.[3,10] Almost half of the professors are obese and it makes the precise measurement of their skinfolds difficult because of the difficult handling of the thick skinfolds. As the skinfold calipers have upper measurement limit, the calipers may not enough to hold the thick skinfold in obese professors. It is a challenge for the enumerators to truly measure the skinfold that consists of a double thickness of skin and underlying adipose tissue leaving the underlying muscle undisturbed. The enumerators may struggle to grasp and hold a large skinfold while reading the caliper dial and it relies highly on the techniques of the enumerators.[14]

When SKF is performed correctly, the results can be compared with hydrostatic weighing which is the gold standard method of body composition. However, when skinfold assessment is not carried out properly, the resulting data and findings may not applicable as it will amplify the potential error. When experienced practitioners measure the same participant, the difference in skinfold site even as little as 1 cm will give significantly distinct results. Therefore, the accuracy of the data largely depends on the skill level of the skinfold technician. In the research, the measurement of BF% are conducted by different enumerators for the total 72 professors. Inter-observer variations and errors may occur because of the different handling of the calipers. The enumerators are trained but not well-trained, they receive training for the measurement event only. Thus, the skills possessed by them may not be proper enough to produce accurate measurement. Besides that, there are few important techniques to yield usable skinfold values including the proper caliper alignment and placement on the fold, duration of measurement (1- to 2-s placement), and the rotation of sites measured during the assessment. It also possible for the measurement error to occur due to error in land-marking the skinfold site.[1,15]

These 2 methods are based on the assumption that the body can be considered

to consist of two compartments of relatively constant composition but which are distinctly different; these compartments are: the body fat, which includes the entire content of chemical fat or lipids in the body, and the fat-free mass (FFM), which includes all the rest of the body apart from fat.[16] But realistically the body is not always made up by constant composition of both fat mass and FFM due to many influencing factors. The variability of the BIA method may be explained by the principles of the method. BIA is based on the principle that different biologic tissues offer various opposition to the electric current passed through. Fat with low quantity of fluids show high resistance while lean tissues with high fluid content are good electrical conductors.[4] Therefore, one's hydration status has great influence on the result of BIA where the states of altered hydration status such as dehydration or water retention can have big impact on the result. Other factors such as moderate to intense physical activity level, consumption of food and beverages before measurements and the use of diuretics may change the measured impedance.[4,6] In addition, the error might be strengthened by variations in the posture of the individual during the exam of BIA, and the contact and location of the electrode. The variations may lead to inconsistent resistance and reactance values, impairing the accurate measurement.[4] The limitations of the research is both the hydration status and physical activity level before measurements are not assessed where these two factors might affect to the measurement of BF% by BIA. Because the data used are secondary data so it is hard to assess the confounding factors that can affect the BF% measurement by SKF and BIA methods.

CONCLUSION

There is no significant difference in the BF% of UNPAD professors measured by the SKF and BIA except those in obese I group. In present study, it cannot be concluded that one method is more accurate than the other due to a gold standard method is not applied as a criterion to be compared with. Suggestion for the future study is to discover a gold standard method to estimate BF% among professors especially elderly professors. Therefore, it is recommended that the choice of which method to use in the application in the daily practice depends on the researches after taking into account of the advantages and disadvantages of the two methods to measure the BF% of the professors.

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REFERENCES

1. Holmstrup ME, Verba SD, Lynn JS. Developing best practices teaching procedures for skinfold assessment: observational examination using the Think Aloud method. Adv Physiol Educ 2015; 39(4):283-7. http://dx.doi.org/10.1152/advan.00044.2015
2. Ostojic S. Estimation of body fat in athletes: skinfold vs bioelectrical impedance. J Sports Med Phys Fitness 2006; 46(3):442-6.
3. Barreira TV, Renfrow MS, Tseh W, Kang M. The validity of 7-site skinfold measurements taken by exercise science students. Int J Exerc Sci 2013; 6(1):20-8.
4. Mialich MS, Maria J, Sicchieri F, Afonso A, Junior J. Analysis of body composition: a critical review of the use of bioelectrical impedance analysis. Int J Clin Nutr 2014; 2(1):1-10.
5. Centres for Disease Control and Prevention. Anthropometry procedures manual. Natl Heal Nutr examinatory Surv 2007; 102.
6. Dehghan M, Merchant AT. Is bioelectrical impedance accurate for use

in large epidemiological studies? Nutr J 2008; 7(1):26. http://dx.doi.org/10.1186/1475-2891-7-26
7. Ordinioha B. The prevalence of hypertension and its modifiable risk factors among lecturers of a medical school in Port Harcourt, south-south Nigeria: implications for control effort. Niger J Clin Pract 2013; 16(1):14. http://dx.doi.org/10.4103/1119-3077.106704
8. King CN, Senn MD. Exercise Testing and Prescription. 7th ed. Avenue of the America. New York: McGraw-Hill; 2011.
9. Undang-Undang Republik Indonesia Nomor 13 Tahun 1998 Tentang Kesejahteraan Lanjut Usia. 1998;1.
10. Neves EB, Ripka WL, Ulbricht L, Wan Stadnik AM. Comparison of the fat percentage obtained by bioimpedance, ultrasound and skinfolds in young adults. Rev Bras Med do Esporte 2013; 19(5):323-7. http://dx.doi.org/10.1590/S1517-86922013000500004
11. Scafoglieri A, Clarys JP, Cattrysse E, Bautmans I. Use of anthropometry for the prediction of regional body tissue distribution in adults: benefits and limitations in clinical practice. Aging Dis 2013; 5(6):373-93. http://dx.doi.org/10.14366/AD.2014.0500373
12. Lovejoy JC, Champagne CM, de Jonge L, Xie H, Smith SR. Increased visceral fat and decreased energy expenditure during the menopausal transition. Int J Obes (Lond) 2008; 32(6):949-58. http://dx.doi.org/10.1038/ijo.2008.25
13. Lin GG, Scott JG. Body composition changes with aging: The cause or the result of alterations in metabolic rate and macronutrient oxidation? NIH Public Access 2012; 100(2):130-4.
14. Duren DL, Sherwood RJ, Czerwinski SA, Lee M, Choh AC, Siervogel RM, *et al*. Body composition methods: comparisons and interpretation. J diabetes Sci Technol 2008; 2(6):1139-46. http://dx.doi.org/10.1177/193229680800200623
15. Keogh MJ, Batt ME. Analysis of body composition : a critical review of the use of bioelectrical impedance analysis. Sport Med 2008; 38(10):863-78. http://dx.doi.org/10.2165/00007256-200838100-00005
16. Wells JC, Fewtrell MS. Measuring body composition. Arch Dis Child 2006; 91(7):612-7. http://dx.doi.org/10.1136/adc.2005.085522