Body composition of Indonesian adults assessed by skinfold thickness and bioelectrical impedance measurements and by a body mass index equation

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Body composition was assessed in Indonesian male (n=29) and female (n=17) students and rural women (n=35) using skinfold thickness measurements, bioelectrical impedance measurements (BIA) with two different equations, and a body mass index equation. Correlation between different methods was significant ($P<0.01$). In rural women and female students fat mass by skinfold measurements was respectively 2.5±2.9 kg ($P<0.01$) and 2.2±2.3 kg ($P<0.01$) lower than by BIA. In male students the difference between skinfold and BIA measurements was 0.8±2.6 kg. Disagreement between methods increased with larger fat mass. In some individuals differences between assessed values were substantial. It is concluded that, especially under field conditions, results obtained by different methods are not interchangeable.

Introduction

One way to determine the nutritional status of individuals is through anthropometrical measurements. Measurement of weight and height is rapid, precise and simple, and the relationship between weight and height provides an indication of an individual's body composition. However, in some cases more precise information on body composition is required, notably the amount of fat mass in relation to total body weight.

In a laboratory setting body composition may be determined through hydrodensitometry[1] or a dilution technique using D_2O^{18} [2]. These methods are regarded as the most reliable assessments of body composition, but they require sophisticated and expensive equipment and experienced, well-trained personnel[3]. Therefore these methods are not suitable in field conditions or in circumstances where resources are limited. Equipment suitable for use under field conditions should be easily transportable, relatively simple to use, and the measurement should be non-invasive and not too time consuming. Equipment that fulfils these criteria are skinfold callipers, used to determine skinfold thickness[4], and bioelectrical impedance analysers used to measure the body's resistance to an electrical current[5]. Furthermore, equations were published recently from which fat mass can be assessed using only an individual's body mass index[6].

Factors that influence body composition are subjects' age and sex, activity and nutrition. However, equations to predict fat mass from skinfold thickness and body mass index, or fat-free mass from impedance measurements, were developed in predominantly white populations that differed in height and weight from most populations in south-east Asia. Furthermore, comparisons between black and white populations indicate that fat patterning differs between ethnic groups[7,8]. Therefore it is of interest to compare several methods used to assess body composition in south-east Asian populations, especially methods which are used frequently.

In this study the body composition of Indonesians was assessed under field conditions using four methods. The aim was to investigate the agreement of the results obtained by the three methods and to determine whether these results could be used interchangeably.

Materials and methods

The study was carried out in West Sumatra, Indonesia. Subjects were selected in the framework of a larger nutritional survey from two different socio-economic groups. Students (29 males and 17 females) were recruited at vocational training institutions in the city of Padang. No female student was pregnant or had a child. The students participated in the nutritional survey, and were selected for this study in order to obtain information on the use of the four methods in young adults. Thirty-five rural women, who were also subjects in the nutritional survey were recruited in their villages in the district of West Pasaman, West Sumatra. The women had 0–11 children, but none were pregnant at the time of measurement. Farming was the main occupation of the rural women. Subjects were recruited on the basis of willingness to participate, and no attempt was made to obtain a random sample of the population. However, subjects were selected to represent a variety of body types. Selected characteristics of subjects are presented in Table 1.

Table 1. Selected physical characteristics and body composition.

	Female students	Rural women	Male students
Number	17	35	29
Age (y)	19.9±0.8*	29.6±6.1	19.9±1.1
Weight (kg)	47.9±6.4	49.8±9.4	57.2±9.5
Height (m)	1.53±0.06	1.49±0.04	1.64±0.07
BMI (kg/m²)	20.2±1.7	22.3±3.8	21.0±2.4
Percentage fat (%)†	25.3±2.8	22.3±5.6	12.8±3.7
Resistance (Ω)	679±57	602±57	505±38
Reactance (Ω)	64±9	53±8	58±6
Sum skinfolds (mm)	45.3±9.3	41.3±17.1	32.3±12.2
Triceps (mm)	13.8±3.5	13.3±4.2	9.5±3.5
Biceps (mm)	7.6±2.0	6.6±3.7	4.4±1.9
Subscapular (mm)	12.6±2.7	12.1±5.1	10.6±3.3
Suprailiac (mm)	12.1±3.0	10.9±6.8	7.8±4.2

* Means ± SD
† As assessed by skinfold measurements.

Body weight was measured to the nearest 0.1 kg using a SECA electronic weighing scale (model 770 alpha; SECA, Hamburg, Germany). Subjects were weighed without shoes and wearing a minimum of clothing. A correction was made for the weight of the clothes. Before use the accuracy of the weighing scale was checked using calibration weights. Height was measured to the nearest 0.1 cm using a microtoise (CMS Weighing Equipment Ltd, London). Subjects stood on a horizontal surface, chin tucked in, stretched upwards to full extent holding the head in a Frankfurt plane. Heels, buttocks and shoulders were in contact with the wall to which the microtoise was attached. Body mass index (BMI) was calculated for every subject from weight and height.

Skinfolds of biceps, triceps, subscapular and suprailiac were measured on the left side of the body in triplicate to the nearest millimetre (if the skinfold was <5 mm, to the next 0.5 mm) using a Holtain calliper (Holtain Ltd, Crymych, Dyfed, Wales, UK). Fat mass was derived from the sum of the four skinfold-thickness measurements and body weight using the equations from Durnin & Womersley[4].

Bioelectrical impedance measurements were carried out with a body composition analyser (Model 101S, RLJ-Systems Inc., Detroit, MI, USA). The analyser was tested before use with a standard 500Ω resistor. Measurements were taken as described by Lukaski et al.[5] with subjects supine, hands at their sides and their thighs apart. To calculate fat-free mass two different equations were used. One equation from Lukaski et al.[9] indicated here as BIA1, and one equation from Deurenberg et al.[10] indicated here as BIA2:

BIA1: $FFM = 0.734\ Ht^2/R + 0.096\ Xc + 0.116\ Wt + 0.878\ G - 4.033$

BIA2: $FFM = 0.652\ Ht^2/R + 3.8\ G + 10.9$

in which FFM is fat-free mass (in kg); Ht is height (in cm); R is resistance (in Ω); Xc is reactance (in Ω); Wt is weight (in kg); and G is gender (1 for men, 0 for women). Fat mass was calculated as the difference between body weight and fat-free mass.

Group differences in fat mass and fat-free mass (as obtained by the different methods) were analysed using the repeated measurements design of analysis of variance (MANOVA, SPSS/PC+ 4.0)[11]; when a significant F-value was obtained ($P<0.05$) paired t-tests were performed. Differences in body composition between the selected groups were tested using unpaired t-tests. Agreement between the two methods is shown by plotting the differences in fat mass against the mean fat mass as obtained by the two methods.[12]

Results

Table 1 shows values of BMI, resistance, reactance and skinfold thickness measurements. The highest sum of skinfolds (45.3±9.3 mm), as well as the lowest average body weight of the three groups of subjects, were measured in the female students. The ratio triceps-subscapular for female students, rural women and male students was respectively 1.12±0.27, 1.12±0.40 and 0.90±0.21.

Table 2. Correlation between the fat mass of three groups of subjects as assessed by four different methods*.

Methods	Subjects		
	Female students (n=17)	Rural women (n=35)	Male students (n±29)
BIA1 vs BIA2	0.995	0.989	0.993
BIA1 vs BMI	0.935	0.909	0.901
BIA1 vs Skinfolds	0.909	0.894	0.883
BIA2 vs BMI	0.947	0.931	0.937
BIA2 vs SKinfolds	0.924	0.901	0.914
BMI vs Skinfolds	0.967	0.933	0.949

* Pearson's correlation coefficient; all methods in all subjects significantly correleated ($P<0.001$).

Table 3. Body composition results.

Methods	Subjects		
	Female† students (n=17)	Rrural† women (n=35)	Male students (n=29)
BIA1			
fat-free mass (kg)	33.4±3.3*	34.3±4.2	48.7±5.4
fat mass (kg)	14.4±4.3	15.5±6.7	8.6±5.2
BIA2			
fat-free mass (kg)	33.8±2.8	35.3±3.4	49.9±4.3
fat mass (kg)	14.0±4.7	14.5±7.9	7.3±6.2
BMI			
fat-free mass (kg)	36.6±4.1	35.3±4.3	49.2±6.5
fat mass (kg)	11.3±2.4	14.5±5.4	8.0±3.2
Skinfolds			
fat-free mass (kg)	35.7±4.2	36.8±4.5	49.4±6.2
fat mass (kg)	12.2±2.7	13.0±5.2	7.8±3.7

* Means ± SD
† Values of fat mass and of fat-free mass as assessed by different methods significantly different ($P<0.05$).

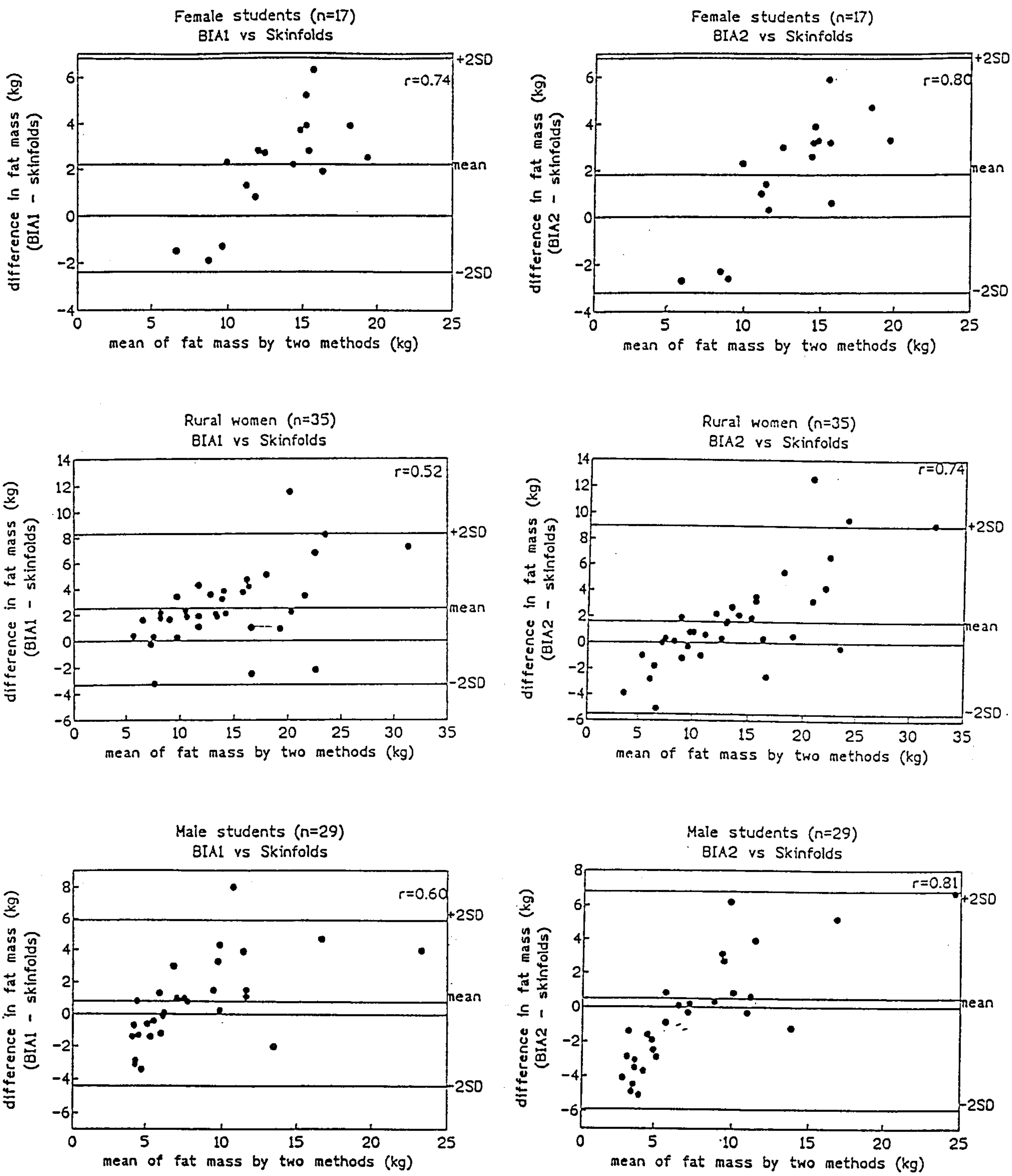

Fig. 1 Difference in fat mass vs mean fat mass for estimates from skinfold-thickness measurement and BIA1, skinfold thickness measurement and BIA2.

Table 2 shows the correlation coefficients between the fat mass estimates for the different groups of subjects. Correlation between each method in each group of subjects was statistically significant ($P<0.001$) with correlation coefficients ranging from 0.88 to 0.99. Correlation between fat mass assessed by skinfold measurements and BIA varied between 0.88 and 0.92. However, a significant high correlation does not mean that the values obtained by the two methods agree, but only that they are related.

The results of body composition assessment by the four methods are presented in Table 3. In all subjects average fat mass assessed by BIA1 gave the highest value. Within female students and rural women, the fat mass values as assessed by the four methods differed significantly as indicated by analysis of variance ($P<0.05$). A similar significant difference existed for the assessed fat-free mass of these two groups.

The agreement between methods is shown well by plots of the difference between two methods against their mean. These plots are shown in Figure 1 for the results of skinfold thickness versus BIA1 and BIA2 methods. Average differences in fat mass assessed by BIA1 method compared to skinfold thickness method were 2.5±2.9 kg in rural women ($P<0.01$), 2.2±2.3 kg in female students ($P<0.01$), and 0.8±2.6 kg ($P<0.13$) in male students. Fat mass differences between BIA2 and skinfold measurements were respectively 1.6±3.7 kg ($P=0.02$), 1.8±2.5 kg ($P<0.01$), and 0.5±3.2 kg ($P=0.82$). The differences between the results obtained from the two methods varied in a systematic way over the range of fat mass as indicated by positive significant correlation coefficients of r (see Figure 1). This means that the disagreement between the skinfold method and the bioelectrical impedance methods increases with larger fat mass of the subjects.

Discussion

Average weight and height of subjects in body composition studies carried out in developing countries in Asia, Africa or Latin America[12-18] were comparable to the values obtained in this Indonesian study. Average values of height and weight of male subjects were less than about 170 cm and 60 kg, and average values of female subjects were less than about 160 cm and 50 kg, respectively. Caucasian male subjects in commonly cited[4-6] body composition studies were on average markedly taller and heavier than the above-mentioned subjects.

In this study on Indonesian subjects, fat mass assessments by skinfold thickness, BIA and BMI methods showed close relationships with significant correlation coefficients of $r > 0.88$ ($P<0.001$). However, fat mass of female students and rural women assessed by skinfold thickness method was on average 1.5–2.5 kg lower than fat mass assessed by the BIA method. Furthermore, with an increased fat mass the disagreement between the fat mass assessments became larger within the groups. This suggests that the discrepancy between BIA and skinfold thickness method in the Indonesian women may be related to the size of the fat mass which is larger in women than in men. This finding, however, cannot be expected in general as indicated by a study in black women[17] where similar fat mass estimations were obtained by BIA and skinfold thickness measurements. Furthermore, fat mass estimations by BIA and skinfold thickness method in white[19-21] subjects resulted in similar average values. A study in British women reported lower fat mass values for BIA compared to seven site skinfold measurements[22]. Figure 1 clearly indicates that within individuals differences in estimated fat mass up to 4 kg are no exception. Differences within individuals are influenced by the precision of the methods. However, a lack of precision does not explain the differences in mean values as indicated by the fact that in male students no statistically significant difference existed between the mean fat mass assessed by the four methods.

With respect to estimates of fat mass from skinfold thickness and BMI measurements it should be considered that the equations used in this study were developed in a white population and suitability for an Indonesian population depends partially on similarities in fat patterning. Fat patterning was reported to be different between white and black adults[7,8,23]. A simple indication for differences in subcutaneous fat patterning can be the triceps-subscapular ratio. Significantly different ratios reported for black and white females were respectively 1.04 and 1.45[8], whereas the Indonesian rural women and the female students both had ratios of 1.12. Norgan et al.[13] compared body composition measurements by skinfold measurement and hydrodensitometry in lean New Guinean adults and reported no significant differences between fat mass estimations. No information was presented on fat patterning in the New Guinean women, but it was concluded that body composition was reliably estimated from equations developed from data from Europeans.

With respect to estimates of fat mass from BIA, the constancy and water content of the fat-free mass can be questioned[24]. The density of the fat-free mass was reported to vary between ethnic groups, which means that the water content of the fat-free mass also varies[25,26]. Usually water content of the fat-free mass is taken as 73.2%, but a range in male adults of 71.1–75.1% has been reported[5]. Changes in water and electrolyte content of the body influence BIA measurements and may lead to errors in fat mass assessment[27]. Furthermore, diurnal changes in fluid balance are likely to occur in tropical countries, and this may negatively effect the validity of fat mass assessments using BIA under field conditions in tropical countries. A study in black West Indian men and women, in which equations for hydrodensitometry derived specifically for blacks were used, reported a systematical underestimation of 0.8 kg of fat mass by BIA compared to hydrodensitometry[28].

Some body composition studies which have compared BIA with other methods have used an original equation developed in their own laboratories[10,19]. In the present study this was not possible because methods which are currently regarded as reliable for assessment of body composition, such as hydrodensitometry or D_2O^{18} dilution technique, were not available, as is the case in many places in developing countries. Since no comparison could be made with such a reliable method, it cannot be concluded which of the four methods used in this study most accurately assessed the body composition of the Indonesian adults. The results of the present study suggest that body composition data assessed by BIA, BMI or skinfold thickness in Indonesian, and probably in south-east Asian subjects should be interpreted with care and that results obtained by different methods are not interchangeable. Direct comparisons between different methods to estimate body composition and a reference method, such as hydrodensitometry or the D_2O^{18} dilution technique, in south-east Asian populations is needed.

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應用皮褶厚度、生物電阻抗和體重指數公式估計印尼成人的身體組成

摘要

作者用皮褶厚度、生物電阻抗（應用兩種不同公式）和體重指數公式估計了印尼男學生（n=29）、女學生（n=17）和農村婦女（n=35）的身體組成。不同方法測得的結果明顯相關（p<0.01）。用皮褶厚度測得的農村婦女和女學生的脂肪質量較生物電阻抗（BIA）測得的結果低，分別相差 2.5±2.9kg（p<0.01）和 2.2±2.3kg（p<0.01）；男學生的脂肪質量相差 0.8±2.6kg。在某些個體估計數值間的差異是巨大的。因而作者認爲，用不同方法得出的結果是不可互換的。

Abstrak

Study tentang komposisi tubuh ('body composition') pada 29 pelajar pria dan 17 pelajar wanita dan 35 wanita pedesaan dilakukan dengan 3 macam pengukuran: 1) Ketebalan lemak dibawah kulit lengan ('skinfold'); 2) bioelektrik inpedance (BIA) dengan dua macam persamaan; 3) perhitungan BMI (Body Mass Index). Hasil antara 3 metode pengukuran tersebut sangat berbeda nyata (P<0.01). Hasil pengukuran bagian lemak dengan menggunakan pengukuran 'skinfold thickness' adalah 2.5±2.9 kg pada wanita pedesaan dan 2.2±2.3 kg pada pelajar wanita, dimana hasil pengukuran ini lebih rendah daripada menggunakan BIA (P<0.01). Peda pelajar pria perbedaan antara pengukuran 'skinfold' dan BIA adalah 0.8±2.6 kg. Ketidak sesuaian diantara 3 metode bertambah besar dengan bertambahnya begian lemak. Pada beberapa individu perbedaan antara yang diuji sangat penting. Sebagai kesimpulan, terutama pada kondisi lapangan, hasil yang diperoleh dengan metode yang berbeda ini tidak dapat saling menggantikan.