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A COMPARISON OF DIFFERENT METHODS OF MEASURING FAT MASS IN HEALTHY INDIANS WITH A WIDE BMI RANGE

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Abstract : The prediction of fat mass from the measurement of bioelectrical impedance has gained popularity because of the ease of performing the measurement. However, the prediction equation used in this method could be specific for a distribution of body size. This study tested the prediction of fat mass in Indian, by the use of an equation based on bioelectrical impedance, which had earlier been generated on a group of low body mass index (BMI 18.15±2.07 kg/m^2) Indians. The impedance method was tested against a standard skinfold method based on the sum of four skinfolds, in a group of 68 Indian males with a large range of BMI (16-26 kg/m^2). The subject were tested as a single group, and were also stratified into four groups based on their BMI, with ranges of BMI between, 15.0-17.9, 18.0-20.9, 21.0-23.9, and >24.0. The mean difference between the estimates of fat mass from the two methods was low in the lowest body mass index (BMI) group (0.91 ± 2.00 kg), with the impedance equation over-estimating the fat mass in all groups. This suggests that the impedance equation should be used with caution in groups whose BMI is above 21.

The distribution of the skinfold thickness revealed that the thickness of the suprailiac skinfold showed the most linear and greatest increment, as the BMI increased across the groups, indicating that it is probably the best single indicator of the fat mass, among the individual skinfolds.

Key words : bioelectrical impedance   skinfolds   BMI

INTRODUCTION

The human body can be divided into two compartments, the fat and the fat free mass (FFM((1). These can be measured by easy to use methods, such as skinfold and bioelectrical impedance methods (2). These methods, while practical, are dependent on the use of predictive equations which relate the measured variable (skinfold thickness or impedance) to the fat mass. Since predictive equations best fit the population from which they are derived, it is possible that an equation derived on a population of

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thin people may not be appropriate for a fatter population. This precludes the general use of predictive equations in different populations, until they are tested. An earlier study (using hydrodensitometry as a reference), had shown the acceptable accuracy of the skinfold method in low BMI (Body Mass Index, Weight (kg)/Height^2 (m) Indians (3). Further, the skinfold equation was generated in subjects whose BMI was comparable to the higher BMI subjects in this study (4); this suggested that the skinfold method was good enough to be used as a reference method in this study, since it could be used in subjects with a range of BMI's.

Body composition measurements using skinfolds, involve measuring the skinfold thickness at different sites. A combination of these skinfolds is then used to determine the body density using regression equation (4), and the fat mass is then calculated from the body density (5). The bioelectrical impedance method to measure the fat mass is based on the principle of passing a minute amount of current through the body and measuring the impedance to the passage of this current (6). The variable (Height^2/ Impedance) generated from these values was, in an earlier report (3), subjected to regression analysis with values of FFM measured by the hydrodensitometric method, by which an equation was generated for FFM estimation. This regression equation was specifically generated using a population with low BMI (mean ± SD, 18.1 ± 2.0 kg/m^2). However, it is not known if this regression equation would apply equally well to Indian with a range of BMI's particularly in the higher range.

There fore, this experiment aimed to evaluate the general applicability of the Indian impedance equation in the measurement of the fat mass of healthy subjects with higher BMI's, in comparison to the same values obtained by skinfold thickness. In addition, this experiment also aimed at studying the skinfold thickness at four sites in order to assess the skinfold which shows maximum change with increasing BMI (or increasing body fat).

METHODS

The study was carried out on a group of 68 males, in the age group of 17 to 25 years. The mean BMI of the whole group was 20.9 ± 2.8 kg/m^2. The subjects were recruited from the student population of St John's Medical College, Bangalore. The subjects were healthy and were not receiving any medication at the time.

The subjects were studied at 6.30 AM, and had been fasted for a duration of eight hours, with no strenuous physical activity eight hours prior to the measurement. The anthropometric and skinfold measurements were carried out immediately. The subjects were weighed in minimal clothing using a digital scale (Soehnle, Germany) which had a precision of 0.1 kg. The height of the subjects was recorded without footwear using a vertically mobile scale (Karrimetre, Sweden) and expressed in centimetres to the nearest 0.1 cm. The following skinfold measurements were made in triplicate in the standing position on the right side of the body and the mean value was taken for the calculation: biceps, triceps, sub-scapular and suprailiac. All measurements were standardized and carried out according to an Anthropometric reference manual (8), and were measured to the nearest 0.2 mm, using skinfold callipers (Holtain, Crymych, UK). The measurements were made by one person for the entire study, and the mean intra-observer variation was 0.25 mm, for four skinfolds, which was within acceptable limits (8).

Bioelectrical impedance, using a bioelectrical impedance meter (Bodystat, Isle of Man, British Isles) and quadrupolar electrodes, was measured after the initial anthropmentry. The procedure was carried out according to the recommendations in the NIH Technological Assessment Statement (6). An alternating current of 800 micro amperes, at a frequency of 50 Hz was applied between the source and the sensor electrodes to provide a measurement of impedance.

The fat free mass (FFM) was calculated by using an equation generated earlier for Indians (3).

$$\text{FFM (kg)} = 16.726 + 0.5977 \times \text{Ht}^2/\text{I}$$

where Ht = Height (cm), and I = Impedance (ohms)

Fat Mass (kg) was then calculated by subtracting the FFM from the body weight.

The logarithm of the sum of four skinfolds, or of combination or either 3 skinfolds, 2 skinfolds, or individual skinfolds was used in gender and age specific equations (4) to obtain the body density, from which estimates of percentage body fat, body fat in kg were made using the equation (5):

$$\text{Fat \%} = [(4.95/\text{Density}) - 4.5] \times 100$$

$$\text{Fat Mass (kg)} = \text{Fat\%} \times \text{Body weight}$$

The fat mass obtained by the skinfold method was compared with the fat mass obtained by the bioimpedance method, using regression, as well as analysis of bias, with skinfold as the reference method. Estimates obtained from the skinfold method were subtracted from the estimates obtained by using bioimpedance (this difference is called the bias), and plotted against the mean fat mass estimate from both methods. This data was also subjected to regression analysis, in order to test if the magnitude of the measurement had any influence on the bias (7). Mean and standard deviation of the bias were also obtained.

Fat mass was also estimated from the sum of three or two, and single skinfolds, in order to test if any particular skinfold, or combination, gave values for the fat mass, which were different form the four skinfold estimate. These data were also subjected to analysis of bias, as detailed above. In addition, the data was also assessed in a stratified fashion, by dividing the subjects into four groups: BMI 15-17.9, BMI 18-20.9, BMI 21-23.9, and BMI > 24 kg/m^2.

Significant differences were tested for by using a One-Way ANOVA, and results were considered so if $P < 0.05$. Data are presented as mean ± SD.

An ethical approval had been obtained in a previous study for the same measurements, by the Ethics Committee of St. Johns Medical College, Bangalore, India.

RESULTS

The anthropometry of the subjects is presented in Table I. Overall, the comparison of fat mass obtained by the bioimpedance method and the sum of four skinfold method yielded a mean bias (difference between the methods) of 6.2 ± 4.1 kg. There was a good correlation between the bias and the magnitude of the estimate (average of the estimate of fat mass

TABLE I : Anthropometry of subjects.

Characteristic	*Mean*	*SD*
Age (Years)	20.0	2.1
Height (cm)	171.6	6.3
Weight (kg)	61.7	10.3
BMI (kg/m^2)	20.9	2.8
MUAC (cm)	27.8	2.9

n = 68

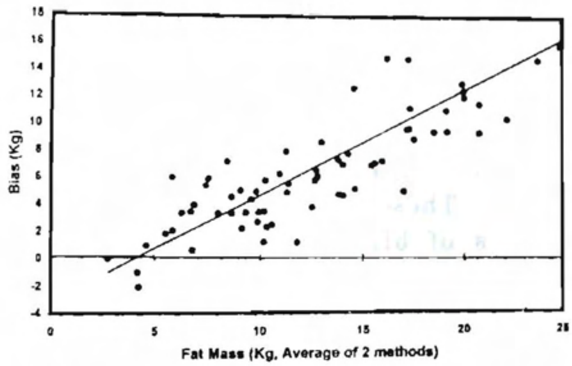

Fig. 1: Linear regression of the bias (kg) of fat mass between the two methods (Impedance and skinfolds) with the average fat mass (kg) of the two methods; r= 0.71, P<0.001.

from both methods), where r = 0.71, P < 0.001 (Fig. 1). This large difference between the methods in the overall data, was primarily due to differences in the higher BMI groups. When the data was stratified according to the BMI groups (see methods), there was a significant trend (One Way ANOVA, P < 0.005) of a higher bias in

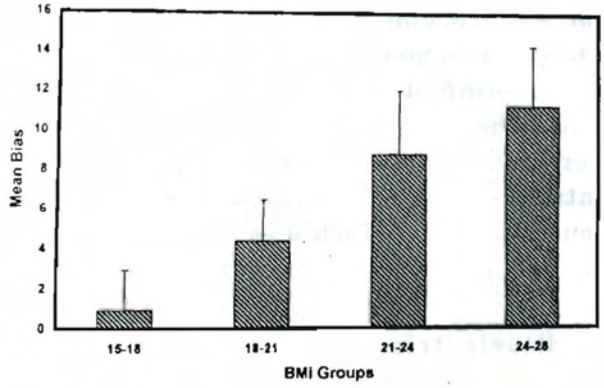

Fig. 2: Mean bias of fat mass between the two methods (kg) in grouped BMI ranges.

the higher BMI groups (Fig. 2), and the bias in the lowest BMI group was also the lowest, at 0.9 ± 2.0 kg. A regression analysis, using the entire group data, between the estimates from the impedance method and the skinfod method, however, showed a very good correlation, r = 0.9, P < 0.001 (Fig. 3).

The estimate of fat mass from four skinfolds (4F) was also compared with estimates of fat mass from combinations of three, two or single skinfolds (3F, 2F, IF respectively). These comparisons, in general, yielded mean differences which ranged from

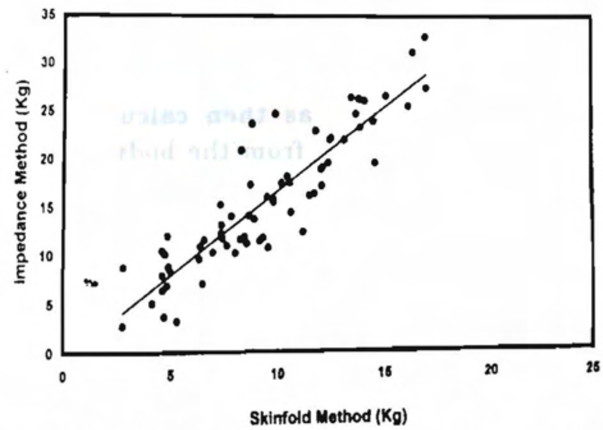

Fig. 3: Linear regression of fat mass (kg) by the Impedance equation with the fat mass (kg) by the skinfold method; r = 0.9, P<0.001.

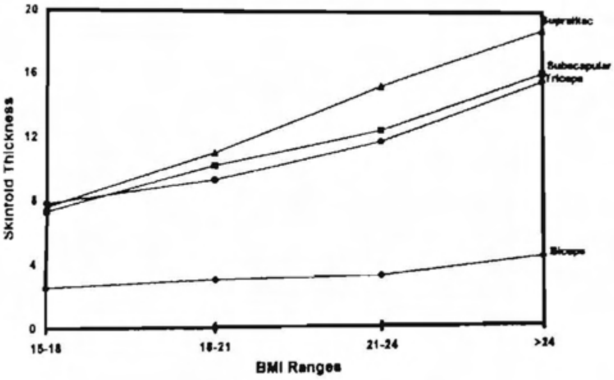

Fig. 4: Mean skinfold thickness (mm) in grouped BMI ranges.

0.02 to 2.15 kg and standard deviations of the mean, ranging from 0.15 to 2.07 kg. The best comparisons were between the combinations of 2 skinfolds (either subscapular and suprailiac, or, triceps and suprailiac) and the sum of four skinfolds. For the single skinfolds methods, the suprailiac and subscapular were the best indicators for fat mass. An analysis of the distribution of skinfolds thickness at the different sites showed that the biceps skinfolds was not significantly affected by increasing BMI, while all the other skinfolds showed almost linear increases with increasing BMI ranges (Table II, Fig 4).

TABLE II : Distribution of the skinfold thickness in the various subgroups. (mm)

	Biceps	*Triceps*	*Subscap*	*Suprailiac*
All Groups n=68	3.2±1.1	10.8±4.5	11.4±3.9	12.9±5.5
BMI 15–18 n=7	2.5±0.3	7.8±2.2	7.3±1.2	7.6±3.4
BMI 18–21 n=32	3.0±0.9	9.3±4.2	10.2±3.0	11.0±4.2
BMI 21–24 n=18	3.2±0.9	11.7±3.3	12.4±3.2	15.2±5.0
BMI>24 n = 11	4.4±1.3	15.5±4.5	16.0±3.7	18.8±4.3

Values are mean ± SD

DISCUSSION

The choice of the skinfold method as the reference in this study was based on an earlier study where the mean difference between the skinfold method and hydrodensitometry was 0.16 ± 1.1 kg, for estimates of FFM (3). The mean FFM in that study was 43 kg, and thus, the bias between the methods was less than 0.5% of the estimate. In addition, the skinfold method used equations derived from studies of males in the same age range, but with a wide range of BMI's (4). A calculation of the range of BMI's in that study, based on an equation that related % fat that to the BMI (9), showed that the BMI ranged from less than 16 to over 40 kg/m2. Therefore, it was decided that the skinfold equations could be used as reference method for this study.

The impedance equation (3) which was derived from an Indian population, applied well to the lower BMI range. The fat mass obtained in these subjects showed a slight positive bias with a standard deviation of approximately 2 kg, which was similar to that recorded in the earlier study which compared the Impedance method with hydrodensitometry (3). In the average and higher BMI ranges, the marked overestimation of fat mass shows that the impedance equation cannot freely be applied to such subjects. The increasing positive bias with increasing fat mass suggests that the systematic error of the estimate increases with the BMI, the values of the SD of the bias in the two higher BMI groups (± 2.00, ± 2.08, ± 3.21, and ± 3.09 kg, in groups 1, 2, 3 and 4 respectively, see Fig 2) also increased, suggesting that the random error was also dependent on the BMI of the individual. The good correlation between the bias and the magnitude of the estimate also suggests that caution be used when individuals of larger BMI are studied.

The fat mass values estimated from combination of either three or two, or from single skinfolds were compared to that of the four skinfold estimate, to establish if smaller numerical combinations of skinfolds could be used. This was particularly for the greater ease which the measurement of fewer skinfolds would offer in a clinical setting, where fat loss or gain would need to be assessed. These estimates, however, yielded varying mean differences from the four-skinfold value, along with high variance (see results). Hence, it is clear that smaller numerical combinations of skinfolds are not suitable for practical use. It is possible however, that these combinations could be used to study serial changes in fat mass in the same subject, although this was not assessed in the present study. Equally, since fat loss or gain may occur from varying sites, it is possible that the smaller combinations may give rise to erroneous results in the same subjects.

The subscapular, the suprailiac and the triceps skinfolds demonstrated a steady increase in thickness as the BMI increased, of which, the suprailiac skinfold was the most linear. This is also reflected in the result that the best combination of skinfolds, (other than the four-skinfold combination), were the two-skinfold combinations, ie, either triceps with suprailiac skinfold, or, the subscapular with the suprailiac skinfold. The biceps fold in this regard seemed to be minimally sensitive.

In conclusion, the present study confirms the applicability of the impedance equation in subjects within a lower BMI range, but demonstrates its inadequacy when applied to average and higher BMI ranges. Skinfold equations using combinations of three, two and single skinfolds do not offer any advantage over the sum of four skinfolds technique, and the suprailiac skinfolds appears to be the best single skinfold for a rough assessment of fat loss or gain.

REFERENCES

1. Lukaski HC. Methods for the assessment of human body composition : traditional and new. *Am J Clin Nutr* 1987; 46: 537–556.
2. Pullicino E, Coward WA, Stubbs RJ, Elia M. Bedside and field method for assessing body composition : Comparison with the deuterium dilution technique. *Eur J Clin Nuir* 1990; 44: 753–762.
3. Kuriyan R, Petracchi C, Ferro-Luzzi A, Shetty PS, Kurpad AV. Validation of expedient methods for measuring body composition in Indian adults. *Indian J Med Res* 1998; 107: 37–45.
4. Durnin JVGA, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr* 1974; 32: 77–97.
5. Siri WE. Body composition from the fluid spaces and density : analysis of methods In: Brozek J, Henschel A, editors. *Techniques for measuring body composition*. Washington DC: National Academy of Sciences NRC, 1961: 223–44.
6. NIH Technological Assessment Statement. Bioelectrical Impedance Analysis in Body Composition Measurement. Bethesda, USA: USDHHS 1994: 1–35.
7. Bland JM, Altman DG Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; i: 307–10.
8. Harrison GG, Buskirk ER, Lindsay Carter ER, Johnston FE, Lohman TG, Pollock ML et al. Skinfold thicknesses and measurement technique. In : Lohman TG, Roche AF, Martorell R, editors. Anthropometric standardization reference manual. Champaign, Illinois : Human Kinetics Books, 1998 : 55–70.
9. Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness age and sex specific prediction formulas. *Br J Nutr* 1991; 65 (2) : 105–114.