Science & Sports (2019) 34, 173.e1—173.e5

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ORIGINAL ARTICLE

# A comparison of bioelectrical impedance analysis and skinfold measurements with Medix DR Dual-energy X-ray absorptiometry for assessment of body fat percentage

## *Comparaison de l'analyse d'impédance bioélectrique et des mesures de plis cutanés avec absorptiométrie à rayons-X double-énergie Medix DR pour l'évaluation du pourcentage de graisse corporelle*

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Received 6 June 2018; accepted 4 March 2019
Available online 23 April 2019

KEYWORDS
Body fat percentage;
Medix DR DXA;
BIA;
Skinfold

**Summary**
*Objectives.* — Body composition can be evaluated using a variety of methods to estimate body fat percentage, but methods tend to vary in precision. The aim of our study is to compare skinfold thickness measurement and bioelectrical impedance analysis to dual-energy x-ray absorptiometry for the estimation of body fat percentage in healthy adults.
*Methods.* — A cross-sectional study design was used to examine and compare body fatness percentage of health adult men and women with three different assessment methods: skinfold thickness measurement (caliper, West Sussex, UK; equations, Jackson and Pollock's and Peterson et al.'s), bioelectrical impedance analysis (Tanita BC 541, Tanita Co., Tokyo, Japan), and dual-energy x-ray absorptiometry (Medix DR, Medilink, France).
*Results.* — Sixty-eight healthy adults aged 19—73 years (34 ± 14.5 years) participated. Mean body fat percentage assessed by DXA (23.2 ± 5.4%) was much less than the body fat percentage estimated by Skinfold using Peterson et al.'s formula (31.7 ± 6.6%), but the relationship between the two was the strongest ($r = 0.903$, $P = 0.000$). Bioelectrical impedance analysis (24.9 ± 8.1%)

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https://doi.org/10.1016/j.scispo.2019.03.002

and Skinfold with J&P's (26.3 ± 9.7%) tended to underestimate DXA-derived body fat percentage in lean and overestimate it in overweight. Body fat percentage produced by Medix DR DXA showed different pattern comparing with other studies in literature, which indicates that more caution should be taken when comparing with other manufactures' results.


**MOTS CLÉS**
Pourcentage de graisse corporelle ;
Medix DR DXA ;
BIA ;
Skinfold

**Résumé**

*Objectifs.* — La composition corporelle peut être évaluée en utilisant une variété de méthodes pour estimer le pourcentage de graisse corporelle, mais les méthodes tendent à être de précision variable. Le but de notre étude est de comparer la mesure de l'épaisseur des plis cutanés et l'analyse de l'impédance bioélectrique avec l'absorptiométrie à rayons X à double énergie pour l'estimation du pourcentage de graisse corporelle chez des adultes en bonne santé.

*Méthodes.* — Une étude transversale a été utilisée pour examiner et comparer le pourcentage de graisse corporelle des hommes et des femmes de santé avec trois méthodes d'évaluation différentes : mesure de l'épaisseur du pli cutané (équations de Jackson et Pollock et Peterson), l'impédance bioélectrique (Tanita BC 541, Tanita Co., Tokyo, Japon), et absorptiométrie à rayons-X à double énergie (Medix DR, Medilink, France).

*Résultats.* — Soixante-huit adultes en bonne santé âgés de 19 à [illegible]5 ans (3[illegible] ± 14,5 ans) ont participé. Le pourcentage moyen de graisse corporelle évalué par DEXA ([illegible],2 ± 5,4 %) était très inférieur au pourcentage de graisse corporelle estimé par les plis cutanés avec la formule de Peterson et al. (31,7 ± 6,6 %), mais la relation entre les deux était plus forte = 0,903, $p$ = 0,000. L'analyse d'impédance bioélectrique (24,[illegible] ± 8,1 %) et le pli cutané avec J&P (26,3 ± 9,7 %) ont tendance à sous-estimer le pourcentage de graisse corporelle que donnerait la DEXA chez les sujets maigres et à la surestimer en cas de poids excessif. Le pourcentage de graisse corporelle donné par Medix DR DXA a montré un modèle différent par rapport à d'autres études dans la littérature, ce qui incite à la prudence quant à la comparaison avec les résultats d'autres fabricants.




## 1. Introduction

Body composition provides an important physiological indication of one's health by detailing the relative contribution of bone, lean tissue, and fat to bodyweight. Estimation of body composition is important to gauge physiological and pathological conditions. The assessment of body composition is frequently used as an outcome measure to determine aspects of exercise science, clinical nutrition and as prevention and treatment strategies for metabolic diseases such as obesity [1]. A variety of indirect methods for estimating body composition have been described in the literature, each of which has advantages and limitations.

Skinfold thickness measurement (SFT) is a long-established method with many optional sets of body sites and prediction formulae. The SFT equations developed by Jackson and Pollock are those of the most widely used equations which were developed by using a two-compartment (2C) model and used Siri's equation. As technology advanced, a four-compartment (4 C) model was introduced (fat, mineral, water, and residual), and a new SFT formula was developed to use 4 C model as the reference [2]. However, the new formula needs more validation.

Bioelectrical impedance analysis (BIA) is a non-invasive, rapid, cost-efficient and portable device. Most BIA devices estimate body fat percentage (BF%) using equations determined by the manufacturer and thus, results may differ between devices and also may alter in response to many factors. Therefore, activities that affect hydration status must be closely controlled.

Dual-energy x-ray absorptiometry (DXA) is viewed as a preferred method to estimate body composition due to its speed, precision, and ability to provide regional measures, but its accessibility, cost and radiation exposure limit widespread use. In addition, manufacturers use different hardware and software for data computation, such the data cannot be compared directly across devices. The Medix DR (Medilink, Montpellier, FRA) is a relatively new DXA device which utilizes a narrow-angle fan beam. To date, however, no body composition validation data exist for the Medix DR device, particularly with reference to SFT and BIA approaches. Thus, our aim was to compare %BF measures for SFT and BIA approaches with %BF derived from the Medix DR DXA device. In this study, we hypothesized that the Medix DR DXA is an accurate method for evaluating body fat percentage in healthy adult.

## 2. Methods

### 2.1. Design

We followed a cross-sectional study design to recruit healthy adults from the local community to undertake body composition assessments. The study was approved by the Griffith University Human Research Ethics Committee (AHS/36/15/HREC). All assessments were undertaken during a single visit to the Bone Densitometry Research Laboratory at Griffith University's Gold Coast campus.

### 2.2. Participants

Men and women from the local community were recruited through advertisements at the University campus and on social media. Participants were older than 18 years of age and were excluded if any of the following applied: irremovable metal in the body, pregnancy, more than two x-ray examinations within the previous 12 months. Participants were initially screened via email prior to testing and instructed to follow specific pre-testing procedures, which included: fasting and abstaining from water for the preceding four hours; no consumption of alcohol for 48 hours or coffee for 12 hours; and abstain from diuretic medications, calcium supplements, or strenuous exercise in the preceding 24 hours.

### 2.3. Anthropometric procedures

Weight was measured to the nearest 0.1 kg, using a mechanical column scale (Seca Scale 700, Seca, Hamburg, Germany) with minimal clothing and without shoes and socks. Standing height was measured to the nearest 0.[illegible] cm, with a wall-mounted stadiometer (Seca 206, Seca, Hamburg, Germany) following standard procedures.

### 2.4. Body composition

#### 2.4.1. Skinfold thicknesses measurements (SFT)

SFT were under taken by a trained anthropometer assessor using a Harpenden caliper (West Sussex, UK), following procedures recommended by the American College of Sports Medicine. The seven measured landmarks were, in order of measurement: chest, midaxillary, triceps, subscapular, suprailiac, abdominal, and thigh. Two sets of skinfold prediction equations were used to calculate %BF. The first set was a seven-site equation developed by Jackson and Pollock (SFTjp) and the multiple regression equations were used to calculate body density (g/mL) and %BF was then calculated according to Siri's equation. The second set applied was four-site (triceps, subscapular, suprailiac and thigh) equations reported by Peterson et al. (SFTnew) [2].

#### 2.4.2. Bioelectrical impedance analysis (BIA)

Participants were asked to step on the Tanita BC 541 scale (Tanita Co., Tokyo, Japan), barefoot. Only one measurement was taken. The device calculates %BF by applying an algorithm that incorporates age, height, sex, and an athlete/non-athlete designation.

#### 2.4.3. Dual-energy x-ray absorptiometry (DXA)

%BF was examined from a whole-body DXA scan using a Medix DR (Medilink, Montpellier, France). Analyses were performed using the corresponding Eazix software. Participants were instructed to remove any metal fixtures before being positioned supine on the DXA device, following the standard positioning protocol.

### 2.5. Statistical analyses

Data are presented as means and standard deviations (SD). Associations between %BF measures for each of the three different methods were examined using Pearson's correlations and the standardized Cronbach's α was employed to test overall consistency. Agreements were examined by calculating mean bias and limits of agreement for %BF between each method and illustrated using Bland-Altman plots. Mean bias (predicted %BF−%BF-DXA) was plotted on the y-axes and the mean of the paired %BF methods was plotted on the x-axes. Limits of agreement were defined as upper and lower 95% CIs and were determined by the mean differences ± 1.96 SD. A *P*-value less than 0.[illegible] was considered to represent a statistically significant difference for all analyses. Software: SPSS (Version [illegible], SPSS Inc, Chicago, USA).

## 3. Results

A total of [illegible] healthy adults (19 to 73 years old) were recruited and underwent body composition testing (Table 1). [illegible] differences between the methods ($P = 0.000$). DXA-derived %BF had the lowest mean (23.2%) and the smallest range (13.4%—36.4%), whereas the mean SFTnew %BF was the highest (31.7%). Acceptable correlations were obtained (Table 2) and the degree of consistency was also high ($\alpha = 0.951$).

Bland-Altman plots (Fig. 1A—C) were used to examine the pattern of bias between the reference method (DXA) and individual methods. It was observed that there were positive relationships between the bias and the average of %BF where SFTjp showed the most distinct pattern ($r = 0.817$, $P = 0.000$), which followed by BIA ($r = 0.650$, $P = 0.000$). For limits of agreement, SFTnew had the lowest range between limits of agreement (95% CI: 2.8 to 14.2%) comparing to the other two comparisons (BIA-DXA: −7.0 to 10.3% and SFTjp-DXA: −7.5 to 13.6%). However, regarding the mean of bias, SFTnew-DXA was the largest with 8.48%. To adjust the results of %BF-SFTnew, general linear regression was performed (Fig. 1D). After regressed, the %BF had identical mean with similar SD (23.2% ± 4.9%) with %BF-DXA and no significant difference (paired-samples *T* Test, $P = 0.991$).

## 4. Discussion

DXA is widely accepted as a standard measurement to estimate %BF [3], and many studies found that SFT and BIA underestimated %BF comparing with DXA. In the present study, however, the opposite results were found, with %BF-DXA presenting the lowest mean and the smallest SD. It is probably because differences exist in the generation of the high and low-energy x-ray beams, the x-ray detector,

**Table 1** Characteristics of the study population ($n = 68$).

| | Total ($n = 68$) | | Male ($n = 29$) | | Female ($n = 39$) | |
|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | Mean | SD |
| Age, (years) | 34.0 | 14.5 | 32.1 | 12.5 | 35.4 | 15.8 |
| BMI, (kg/m$^2$) | 24.6 | 3.7 | 26.4 | 4.3 | 23.3 | 2.6 |
| Height, (cm) | 170.0 | 8.5 | 175.9 | 7.0 | 165.6 | 6.7 |
| Weight, (kg) | 71.6 | 14.5 | 81.8 | 14.9 | 63.9 | 8.3 |
| %BF-DXA | 23.2 | 5.4 | 19.8 | 4.1 | 25.7 | 4.8 |
| %BF-BIA | 24.9 | 8.1 | 20.2 | 7.3 | 28.4 | 6.9 |
| %BF-SFTjp | 26.3 | 9.7 | 20.5 | 8.9 | 30.7 | 7.8 |
| %BF-SFTnew | 31.7 | 6.6 | 26.9 | 6.0 | [illegible] | 4.5 |

**Table 2** Pearson correlations for %BF measures according to device.

| | DXA | BIA | SFTjp | SFTnew |
|---|---|---|---|---|
| DXA | 1.000 | | | |
| BIA | 0.865[a] | 1.000 | | |
| SFTjp | 0.898[a] | 0.876[a] | 1.000 | |
| SFTnew | 0.903[a] | 0.829[a] | 0.926[a] | 1.000 |

[a] Significance level: $P$-value = 0.000.

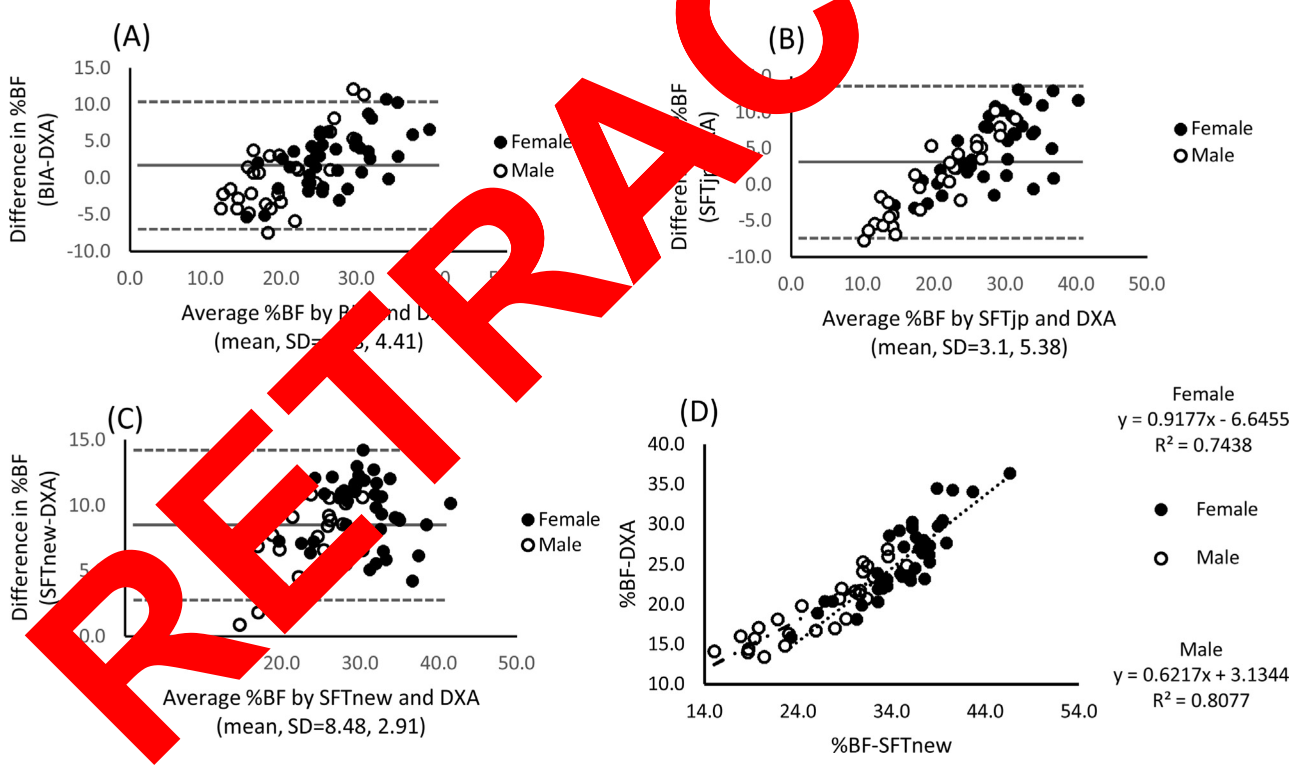


**Figure 1** Plots of differences and mean values of %BF (A, B and C) and the comparison of %BF-DXA with %BF-SFTnew (D). Upper panel right shows BIA vs. DXA, upper panel left shows SFTjp vs. DXA and lower panel left shows SFTnew vs. DXA (the solid lines indicate the mean of bias and the dashed lines refer to mean ± 1.96 SD).

the imaging geometry, and the calibration methodology between Medix DR and other machines. In addition, results from the present study show that the range of %BF-DXA was between 13.4% and 36.4%, which was the narrowest. The reason may either be the changes of position in large sized participants (as there was not enough scanning space to keep the standard position for such participants), or the percentage body fat measured by DAX never be too low [4].

In Bland-Altman plots, both BIA vs. DXA and SFTjp vs. DXA showed slopes which indicated the differences became larger with the rising bias, and the trend was much obvious in SFTjp. Comparing to DXA, both BIA and SFTjp tended to underestimate %BF when the mean was under 20% (men mostly), and to overestimate when it was above 30% (women mostly). However, Serkan Duz et al. found opposite trend, which with the increased mean, both SFT and BIA constantly inclined to underestimate the %BF-DXA [5]. The difference in the results may in part result from the difference in devices and the equations, and the formation of participants (they only investigated young people, 18—27 years) may also be one of other explanations. Moreover, SFTjp produced the largest range of bias (21%) than the other methods, which means it could false predict the %BF-DXA by approximately 10%. Although SFTjp had rather high level of correlation with DXA ($r = 0.898$, $P = 0.000$), this method was not applicable, especially to very lean or obese population.

The results of BIA BF% had a relatively high correlation with DXA ($r = 0.865$, $P = 0.000$) and the lowest bias (1.68%) with moderate wide limits of agreement (17%). This indicated that Tanita BC 541 scale (Tanita Co., Tokyo, Japan) may produce acceptable %BF, but with caution of body hydrated condition.

The %BF yielded by SFTnew appeared much more random in the Bland-Altman plot, and had the narrowest range of limits of agreement, as well as the strongest relationship with %BF-DXA, which made the method the best among the three to predict %BF-DXA. But when the bias was considered (almost 10% more than DXA in women, and 7% in men), the results could not be much trustful. This is probably because DXA, which is based on a 3-compartment model (fat, b[illegible] mineral and residual) [6], tends to progressively underes[illegible] mate the body fat of leaner individuals compared with th[illegible] 4 C model [3], which the SFTnew equations we[illegible] based on [2]. In other words, SFTnew could overesti[illegible] -DXA, and the lower the %BF, the higher was t[illegible] bias. H[illegible] vever, Ploeg et al. [3] reported that the mean [illegible] renc[illegible] 4 C model and DXA was 1.8%, and th[illegible] ias b[illegible] n SFTnew and DXA in the present study was [illegible] %, and in [illegible] ition, %BF yielded by SFTnew was also much higher than by BIA and SFTjp. This indicated the new equation needs modification according to different population.

## 5. Conclusion

In our study, %BF produced by Medix DR DXA machine showed some different pattern comparing with other studies in literature which used either Lunar or Hologic, which indicates that more caution should be taken when comparing the results of %BF from different manufactures. In addition, compared with Medix DR DXA derived b[illegible] percentage, BIA showed moderate accuracy and [illegible] four-[illegible] SFT with new equations overestimated it.

## Disclosure of interest

The authors declare tha[illegible] ey [illegible] e no competing interest.

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