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BODY COMPOSITION OF FEMALE OFFICE WORKERS COMPARED WITH INFRARED REFLECTION MEASUREMENT, BIOIMPEDANCE ANALYSIS AND CALIPERMETRY

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ABSTRACT

There are currently many different anthropometric methods for determining the individual body fat percentage, as well as almost as many variants of bioelectric impedance analysis (BIA) and only a single method of infrared reflection measurement (IR) as easily available methods of field research.

The present study aims at a simultaneous comparison between calipermetry, IR and BIA. In particular, the question which measurement method could be used as an equivalent method in the event of failure of BIA or IR is investigated.

The sample group consisted of 121 female office workers (average age 32.5 ± 9.4 years, average height 164.5 ± 6.3 cm and average weight 60.3 ± 6.8 kg), from the Rhine-Main area.

The measurements were previously scheduled and mostly carried out during the lunch break. For anthropometry, 13 skin fat folds were measured with the Accu® Measure Caliper, thigh circumference with a measuring tape, the height with a height measuring device and the body mass on the weight scale. Subsequently, an IR measurement (Futrex®) and a BIA (InBody®) were performed on the same subjects.

The parameters of body fat percentage and total body water (in L) were examined.

Statistical methods were correlation coefficients, Bland-Altman comparison and paired *t*-test for equivalence.

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For the women studied, the highest correlation coefficients were in the comparisons between the formulas according to Parízková and Brožek et al. (r = 0.82), as well as for Parízková and Siri (r = 0.82).

The correlation coefficient for the IR vs. BIA comparison was r = 0.92.

A key result of the present study was the finding that the investigated methods in a female study group could not be substituted in an equivalent way.

Keywords: *percentage of body fat; bioimpedance analysis; calipermetry; infrared reflection measurement; body composition; women*

INTRODUCTION

After our working group had already presented a comparative study last year [13] on the methods frequently used in sports medicine, general medicine and internal medicine practice for determining body composition with bioimpedance analysis (BIA), infrared reflection measurement and calipermetry in males, the present study now focuses on a comparative survey of women. Above all, the regression equations in women are known to differ considerably from those of men in calipermetry. Skin fold measurement as a method for assessing the total body fat mass is based on the fact that 50–70% of the fat deposits are located in the subcutaneous fatty tissue. By means of a special anthropometric instrument, the caliper, skin fold thickness can be measured at defined parts of the body [5, 8, 10–12, 16, 17].

In infrared reflection measurement, the measuring head of the device emits a near-infrared light beam with a certain wavelength into the biceps. The direct measurement of body fat mass is based on the different absorption and reflection values of different tissue types [7].

The basis of bioelectrical impedance analysis is the fact that different tissue and cell types of the human body conduct electric current well. Impedance is composed of resistance and reactance. The non-cellularly bound body fluid behaves like an electrical conductor that opposes the current with a simple ohmic resistance called resistance (R). Reactance (Xc) is the capacitive resistance caused by the capacitor properties of the body’s cells. Using the resistance value (resistance of the body water), the total body water is calculated via the impedance index. By determining the total body water, the fat-free mass is calculated. Here, the total body water is divided by the factor 0.732, since it is assumed that about 73% of the fat-free mass consists of body water [5, 8, 11, 12, 16]. Body fat mass can be calculated by subtracting the fat-free mass from the total body weight.

The aim of the present study was to compare the values determined in the context of a body composition analysis by the measurement methods of calipermetry, infrared reflection measurement and bioelectrical impedance analysis in women and to assess to what extent the results of the measurement methods used correlate with each other. The focus is on the percentage of body fat and the total body water (in L).

METHODOLOGY

A total of 121 women were examined (average age 32.5 ± 9.4 years, range 18–55 years; median 32 years; average height 164.8 ± 6.3 cm, range 150–184 cm, median 165 cm; average weight 60.3 ± 6.8 kg, range 44.5–87.9 kg, median 59.4 kg). Two age groups, between 20–24 and 35–39 years, made up the largest share of the group with 19.8 and 19.1% respectively. The subjects were recruited from the area around the cities of Frankfurt am Main, Offenbach am Main and Darmstadt.

The Accu® Measure from the manufacturer AuccFitness was used as the caliper.

The study was carried out using the regression equations according to Möhr & Johnson [9], Parízková [10], Siri [15], Brožek et al. [3] and Weltman & Katch [17].

The measurement with the FUTREX Body Fat Analyzer 6100/XL takes place in a sitting position. The exact location of the measuring point is determined with the "Elbowmeter". Light absorption is the decisive factor in determining the body fat percentage. The measurement takes about one minute [11, 12].

Bioelectrical impedance analysis was carried out with InBody® 230 of the company Biospace. The technology is based on segmental multi-frequency measurement with tetrapolar 8-electrode technology. The analysis with InBody® 230 is carried out while standing [11, 12].

In addition to Pearson's correlation coefficient, Bland-Altman analysis [1, 2] was used for the statistics, with which the two methods used in the same experimental group were compared. In the Bland-Altman plot, the difference (di = Xi–Yi) is plotted on the ordinate against the mean (MW = (Xi–Yi) / 2) on the abscissa.

In addition to Bland-Altman analysis, the paired *t*-test for equivalence was used. Commercial statistical programs such as EViews 6&7 from Quantitative Micro Software, WisStat from R. Fitch and NCSS version 12 were used to prepare the measured values.

RESULTS

Averages of body fat percentage are given in Table 1. All averages range from 27.8% to 33.7%. The average value of the mean values is 31.7%. At 32.6%, the average values according to Möhr & Johnson [9] are closest to the average of all mean values. The regression equation according to Weltman & Katch [18] implies the largest standard deviation (7.1).

Only two comparisons have a correlation coefficient above 0.8. These include the comparisons between Parízková [10] and Brožek et al. [3] and Parízková [10] and Siri [15].

The comparison of the regression equations according to Parízková [10] with Brožek et al. [3] has a correlation coefficient of 0.82.

Table 1. Mean values of body fat percentage

Fat percentage	Average	Standard deviation
Möhr & Johnson (9)	32.6	4.2
Parízková (10)	29.4	3.6
Brožek et al. (3)	33.7	5.9
Siri (15)	35.1	6.5
Weltman & Katch (18)	27.8	7.1

Except for a few points, all points are within the confidence limit (Fig. 1).

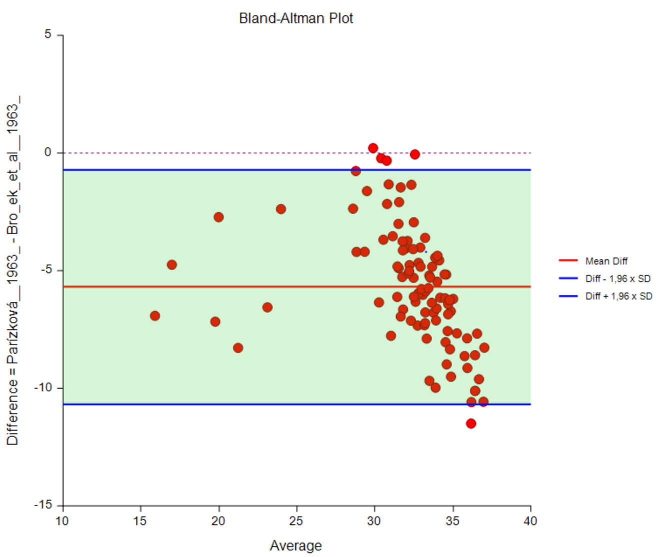

Figure 1. Bland Altman Plot, Parızková vs. Brožek et al.

The *t*-test to check equivalence results in a p-value of 1.00. Thus, equivalence is not assumed.

The comparison between the regression equations according to Parízková [10] and Siri [15] has the same correlation coefficient as the comparison between Parízková [10] and Brožek et al. [3]. Here, too, the correlation coefficient is 0.82.

The *t*-test for checking equivalence also results in a p-value of 1.00. Thus, equivalence is not assumed (Fig. 2).

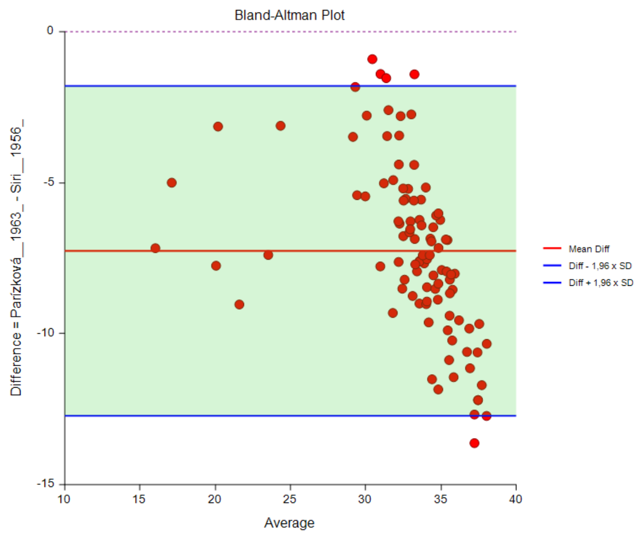

Figure 2. Bland Altman Plot, Parızková vs. Siri et al.

The comparison between infrared reflection measurement and bioelectrical impedance analysis shows that the mean values in the women's group are 26.1 ± 4.1% and 27.7% respectively ± 4.7%. The average value of the mean values is 26.9% (Fig. 3).

A relatively low correlation coefficient can be seen; r = 0.62. For this purpose, the results of 121 women were taken into account. The *t*-test for checking equivalence also results in a p-value of 0.93. Thus, equivalence is not assumed.

Infrared reflection measurement and bioelectrical impedance analysis thus have an even lower correlation with each other but also in comparison to calipermetry, which is therefore no longer described in more detail for reasons of space.

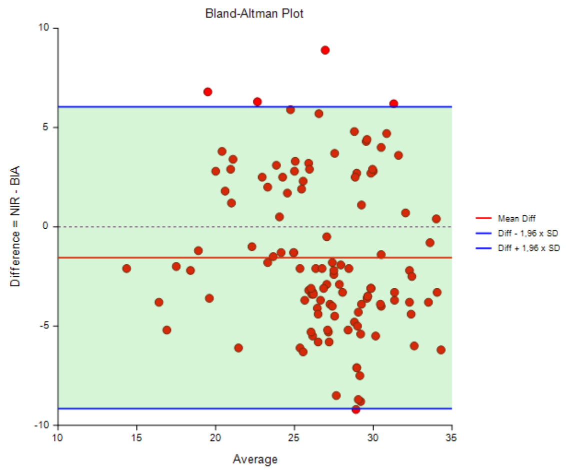

Figure 3. Bland Altman Plot, BIA vs. IR

Since total body water can only be measured by infrared reflection measurement and bioelectrical impedance analysis, only the comparison of these two methods is shown. It can be seen that the mean values are relatively close to each other (BIA 32.6 ± 4.2 l; IR 31.8 ± 4.1 l).

The comparison between infrared reflection measurement and bioelectrical impedance analysis has a correlation coefficient of r = 0.92.

The *t*-test to test equivalence results in a p-value of 0.99. Thus, equivalence is not assumed. For this purpose, the measurement results of 121 women were taken into account (Fig. 4).

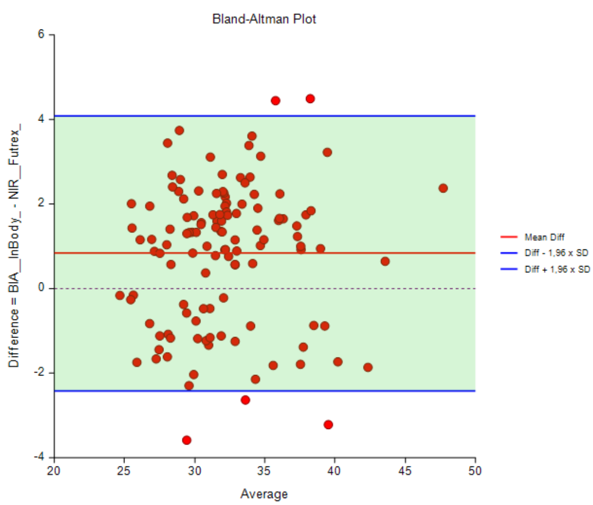

Figure 4. Bland Altman Plot, total body water (in L), BIA vs. IR

DISCUSSION

The topic of the present study is a comparison of measurement methods in the female sex. All the three measuring methods used can be purchased in the trade without great difficulty.

Already during the briefing discussions, it turned out that the willingness to be measured in lightly clothing with a caliper was relatively lower among women compared to the survey of a men's sample a year ago. As an argument for not participating, "unhygienic conditions", referring to the barefoot measurement of bioelectrical impedance analysis, "shyness of nudity" and "unpleasant measurement methodology", particularly calipermetry, were mentioned.

The results of the study show that, with infrared reflection measurement and bioelectrical impedance analysis, a fast, simple body composition analysis is possible.

Since many different regression equations can be found in calipermetry and the measurement methodology was considered embarrassing by some, the application of infrared reflection measurement or bioelectrical impedance analysis is likely to be more advantageous for certain samples.

Price comparison favours calipermetry. Although the current price of a classic Harpenden skinfold Caliper® is still €290, new plastic calipers are now available for 10% of this sum. A BIA device like the one used in the study costs about €18,000, the Futrex® Body-Fat Analyzer at least €4000.

The higher risk of failure due to a potential technical defect of the very complex apparatus also speaks against the electrical devices. Lightning strikes, power failures, and other disruptive factors should also be considered. In such a case, a replacement method should definitely be available, as both competitive athletes and patients can often come from a larger catchment area.

Furthermore, conspicuous individual cases of measurement values could also be checked by another method.

According to Herm [5], the fat content obtained by impedance measurement is up to 6.8% higher than the results of skinfold measurements. One can only agree with his demand for the standardization of impedance measurement and restriction of the variety of devices.

As early as in 2003, Herm [5] called for a method-critical examination of BIA and infrared measurement and, as a conclusion, recommended the determination of body fat by means of calipermetry of defined skin folds as a sufficiently reliable and practicable method.

In a chronobiological study, Raschka et al. [14] compared calipermetry [8] as well as the anthropometric formula according to Weltman and Katch [18], BIA (Data Input device) and IR to determine the percentage of fat in 24 active athletes. There were significant differences between the individual methods, with the lowest values being recorded calipermetrically, and the highest values with the Weltman/Katch formula. IR values and Weltman/Katch data were least affected by the ultradian influences. In principle, the BIA is very good at recording fluid shifts during the chronobiological course of the day, as Dittmar et al. [4] could show.

However, which method for determining the body composition, in particular the percentage of fat, can possibly be meaningfully replaced by which identification alternative? An example of this is the change of the family doctor (possibly when moving to another city), change of the gym, the trainer, the supervisor or the sports medical examination office. For example, how should a change in the percentage of fat, which perhaps amounted to 13.5% in the previous year (measured e.g., with BIA), be interpreted if the fat content at another examination site is now 17.1% (measured e.g., with IR).

The following two points should be emphasized:
1. Percentage of fat in female subjects, calipermetric: There were no significant equivalences here, so that it makes no sense to replace one method with another.
2. Percentage of fat, BIA vs. IR: There were no significant equivalences here, either.

This would mean that an exchange of different methods on the basis of diverging measurement principles (e.g., calipermetry vs. BIA vs. INR) is generally not useful. With regard to total body water, IR and BIA are not equivalent, either.

This would be interesting, for example, for samples where the hydrogenation status is in the foreground. In addition to special patient samples such as dialysis patients, all persons for whom a certain altitude exposure is relevant (e.g., mountaineers, hikers, trekking, etc.) should be named here.

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