REPRODUCIBILITY AND WITHIN-DAY VARIABILITY OF BODY FAT MEASUREMENTS USING SEGMENTAL BIPOLAR BIOELECTRICAL IMPEDANCE IN WOMEN

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Resumo

Objectivos: existe pouca informação disponível sobre a reprodutibilidade dos aparelhos de medida da massa gorda. Neste estudo, procurou-se determinar a reprodutibilidade inter e intra-aparelho, assim como a variação das medidas ao longo do dia.

Material e métodos: a percentagem de gordura corporal foi medida em duplicado em 16 estudantes do sexo feminino, com idades entre os 18 e 20 anos e um índice de massa corporal de 21.9 ± 2.5 kg/m² (média ± desvio-padrão), utilizando sete aparelhos de bioimpedância bipolar. As participantes foram seguidamente medidas todas as horas entre as 7:00 e as 22:00.

Resultados: a correlação entre medidas efectuadas por um mesmo aparelho era muito elevada (r de Spearman entre 0.985 e 1.000, p<0.001), tal como entre as medidas efectuadas por aparelhos diferentes (r de Spearman entre 0.916 e 0.991, p<0.001). Uma análise de variância de medidas repetidas não mostrou diferenças entre aparelhos (p=0.59) ou entre a primeira e a segunda medida (p=0.74). Em contrapartida, foram detectadas diferenças significativas no que toca às medidas efectuadas ao longo do dia: as medidas feitas no período da manhã eram significativamente mais baixas do que as efectuadas no período da tarde (teste F para medidas repetidas =6.58, p<0.001).

Conclusão: a reprodutibilidade inter e intra-aparelho de bioimpedância bipolar é elevada, o que permite utilizar vários aparelhos de medição no mesmo estudo. Em contrapartida, as medidas efectuadas apresentam flutuações significativas durante o dia, o que obriga a efectuar as medidas a horas fixas.

Palavras-chave:
Composição corporal; Reprodutibilidade; Mulheres; Bioimpedância; Aparelho Bipolar

Abstract

Background and aims: little is known regarding the reproducibility of body fat measuring devices; hence, we assessed the between and within-device reproducibility, and the within-day variability of body fat measurements.

Methods: body fat percentage was measured twice on seventeen female students aged between 18 and 20 with a body mass index of 21.9 ± 2.5 kg/m² (mean ± SD) using seven bipolar bioelectrical impedance devices. Each participant was also measured each hour between 7:00 and 22:00.

Results: the correlation between first and second measurements was very high (Spearman r between 0.985 and 1.000, p<0.001), as well as between devices (Spearman r between 0.916 and 0.991, p<0.001). Repeated measurements analysis showed no differences were between devices (p=0.59) or readings (first vs. second: p=0.74). Conversely, significant differences were found between assessment periods throughout the day, measurements made in the morning being lower than those made in the afternoon (F test for repeated values=6.58, p<0.001).

Conclusions: the between and within-device reproducibility for measuring body fat is high, enabling the use of multiple devices in a single study. Conversely, small but significant changes in body fat measurements occur during the day, urging body fat measurements to be performed at fixed times.

Keywords:
Body composition; Reproducibility; Women; Bioimpedance; Bipolar device

INTRODUCTION

Body fat has been shown to be more related to cardiovascular disease than other markers of obesity such as BMI or waist[1-3]. Body fat can be measured by different methods such as underwater weighting or double energy X-ray absorption, but when large samples are needed such as in epidemiological studies, only methods based on skin fold or bioimpedance measurements can be routinely used.

Recently, several lightweight devices measuring body fat percentage via bioimpedance have appeared in the market. Those devices can be either hand-to-hand or foot-to-foot, and several studies have shown that they adequately measure body fat when compared with reference methods[4-7] although this statement has been challenged[5,8,9]. Still, little is known regarding the reproducibility of those devices and the stability of the measures throughout the day. Hence, we conducted a study aimed at assessing the between- and within-device reproducibility, as well as within-day variability of body fat measurements using a hand-held, bipolar bioimpedance device.

METHODS AND PROCEDURES

Sample

This work was part of the curriculum of the Nutrition and Dietetics course of the Medical Faculty of the Lisbon University and as such no approval from the Ethics Committee was sought. One of the lectures is aimed at acquainting the first year students to the characteristics (including variability) of the different body composition measurement techniques. Overall, 19 students (17 women, 2 men) aged between 18 and 20 took part in the study; as the number of male students was very low, they were not analysed.

Body fat measurements

Before measurements, all students were asked if they presented any contraindication to bioimpedance (pacemaker and/or pregnancy). Measurements were conducted using six BF-306 OMRON devices (OMRON, Japan), which has been shown to produce results close to dual-energy X-ray absorptiometry[5], the results were expressed as percentage of body weight. Briefly, the subject stood with the feet slightly separated, holding the device in both hands, arms stretched out at an angle of 90 degrees relative to the body. The instrument records impedance from hand to hand and subsequently calculates % body fat to the nearest 0.1% based on age, gender, height and weight[10]. No information regarding the formulas used to calculate the % of body fat could be obtained from the manufacturer.

Body fat measurements were conducted in two steps. In the first step, ten female and two male students assessed their body fat using all the available devices (six devices). The devices were randomly allocated and each student made two sequential measurements using the same device. In the second step, each student measured his/her body fat twice each hour starting at 7:00 and ending between 21:00 and 22:00 and reported the mean value of each two measurements. Again, the devices were randomly allocated to the students. The students used a single weight value (measured at noon) to calculate body fat % and were instructed to keep their usual daily living activities but to restrain from exercising or increased physical activity throughout the day.

Statistical analysis

Statistical analysis was conducted using SAS version 9.2 (SAS Inc., Cary, North Carolina, USA) for Windows®. For each participant, the average body fat was computed from all measurements conducted throughout the day and a relative percentage (% of average) was computed for each hourly assessment of body fat; results were expressed as mean ± standard deviation. Correlations within and between devices were assessed using average values from duplicate measurements obtained from each device by Spearman nonparametric correlation coefficients. Differences between devices and between measuring times were further assessed by repeated measurement analysis[9] using a general linear model (proc GLM of SAS). For each participant, body fat variation within time was computed using linear regression and equality of slopes was assessed using analysis of covariance (ANCOVA). Statistical significance was considered for $p<0.05$.

RESULTS

Reproducibility study

Seventeen female students (age 18-19 years, mean ± SD weight 58.7 ± 5.2 kg, height 164 ± 5 cm and BMI 21.9 ± 2.5 kg/m^2) participated in the study. One was overweight and none was obese.

For all devices, the within-device correlations between the first and the second measurement were very high (Spearman r between 0.985 and 1.000, $p<0.001$). The correlations between devices are summarized in table 1. Very high correlations were also obtained, the lowest being 0.916 and the highest 0.991. Finally, repeated measurements analysis showed no differences were between devices (F test=0.83, p=0.59) or readings (first vs. second: F test=0.12, p=0.74).

Table 1 — Correlation matrix between different body fat measurement devices.

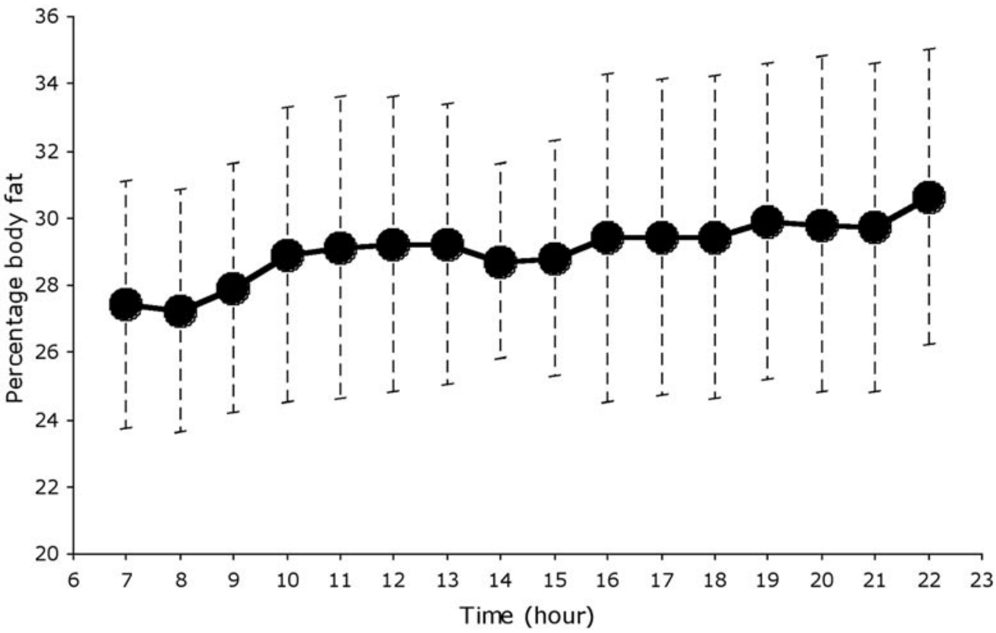
Device #	1	2	3	4	5
2	0.986				
3	0.985	0.958			
4	0.967	0.916	0.984		
5	0.976	0.940	0.983	0.991	
6	0.960	0.959	0.921	0.933	0.961

Results are expressed as Spearman nonparametric correlation coefficient (n=10). All coefficients are significant at $p<0.001$.

Circadian study

Of the seventeen female students, one decided not to participate in the measuring procedure throughout the day. Data on the circadian evolution of %BF is thus presented for sixteen female students. Significant differences were found between assessment periods throughout the day, measurements made in the morning being lower than those made in the afternoon. Assuming an overall daily average of 100 (based on all measurements for a given participant), the values were 95.8 ± 3.2 (mean ± SD) at 8:00 versus 101.3 ± 3.0 at 20:00, corresponding to a mean change of 2.2 ± 1.1 units in %BF (F test for equality of hourly measurements=6.58, $p<0.001$) – figure 1.

Figure 1 — Circadian variation of body fat measurements in 16 women. Results are expressed as mean ± SD for body fat percentage. Analysis by ANOVA for repeated values; F test for equality of hourly measurements = 6.58, $p<0.001$.



Most participants showed an increase in their body fat measurements with time, with the exception of one participant, for which a significant decrease in body fat with time was noted. ANCOVA analysis showed significant differences in slopes between participants (test=2.16, p=0.01).

DISCUSSION

Although most epidemiological studies assess clinical data on a fixed day period with a single device, others must rely on measurements performed throughout the day or using multiple devices (such as the case of multicentric studies). As devices have to be properly calibrated to obtain comparable measurements between centers, our study thus provide important information regarding the applicability of hand-held bioimpedance devices in multicentric studies. Further, to our knowledge, this is the first ever study reporting on the between- and within-device reproducibility, as well as the circadian variability of a hand-held, bipolar bioimpedance device.

Reproducibility of the hand-held device was good, the correlations (between sequential measurements or between devices) being very high and comparable to those reported for other devices[7,11]. Also, no difference in mean values was found between devices, thus suggesting that they can be easily and securely used in multicentric studies.

Individual body fat measurements are influenced by a variety of factors such as temperature[12], exercise[13], sweating[13], posture change[14] or food/beverage ingestion[13], although this statement has been challenged[15-18]. Further, although the effect might be clinically irrelevant for an individual[16], still at the population level even small changes might result in falsely significant differences. Hence, it is of uttermost importance to properly assess the impact of measurement time if body fat measurements are to be conducted throughout the day.

Body fat percentage increased during the day. Those findings are in agreement with a previous study[19] and indicate that significant differences in individual body fat assessment occur when measurements are conducted at different times of the day. Possible explanations include a decreased body hydration[20] or a fluid shift from the upper to the lower part of the body[14,21], which would increase upper body resistance and thus influence body fat measurements. Other explanations such as changes in body weight cannot be ruled out, but it has been shown that even in the presence of a constant body weight an increase in body fat during the day is still found[19]. It has also been shown that the ingestion of meals leads to an additive decrease in bioelectrical impedance and body fat[22,23]; still, in this study, neither decrease in body fat after meal consumption nor cumulative effect was found. The reasons for an increase in body fat percentage during the day are not straightforward and might depend on the participants' type of meal, hydration or physical activity, as significant between-participant differences were found regarding evolution of body fat measurements during the day. Hence, independently of a precise explanation for the increase in body fat or putative effect of meals, our results stress the need for a strict standardization of body fat measurements, both in epidemiological studies and clinical practice.

This study has some limitations. For instance, most participants were young, normal weight women, and it is not known if the results would also apply to older or overweight women. As all students used the same weight (assessed at noon) to measure body fat percentage, and it has been shown that body weight presents some variations throughout the day, which might be partly responsible for the circadian variations in body fat. Still, it would prove too difficult to ask the students to weight themselves each hour, and it is unlikely that such a variation in weight would have occurred. Also, only data from two male students was available, thus precluded adequate statistical analysis, and it is not known if the results obtained in women also apply to men. Hence, it would be of interest to replicate this study among men and older subjects presenting with overweight or obesity in order to confirm the findings.

CONCLUSION

In summary, our results indicate that, in young women, the between and within-device reproducibility of OMRON BF-306 hand-held body fat measurement devices is high, enabling the use of multiple devices in a single study. Conversely, small but significant changes in body fat occur during the day, urging body fat measurements to be performed at fixed times.

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CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.

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