Journal of
PHYSIOLOGICAL
ANTHROPOLOGY
and Applied Human Science

The Influence of Posture Change on Measurements of Relative Body Fat in the Bioimpedance Analysis Method

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Abstract The purpose of this study was to clarify the influence of posture change on relative body fat in the bioelectrical impedance analysis (BIA) method. The subjects were 30 Japanese healthy young adult males (age: 19.8 ± 1.4 years, height: 172.3 ± 5.8 cm, weight: 67.1 ± 8.2 kg). We used devices with different body segment inductions, between the hand and foot (H-F BIA) and between hands (H-H BIA), and set four measurement conditions differing in posture (supine or sitting), during rest and measurement. The reliabilities of %BF in the H-H and H-F BIA methods were very high (r=0.995, 0.966), and the relationship in %BF between the UW method and each BIA method was mid-range (r=0.767, 0.709). Although there were no differences in %BF among different measurement postures in the H-F BIA method, %BF in the H-H BIA method increased significantly when the posture was changed just before measurement. This indicated that it is necessary to pay attention to the posture change just before measurement in the H-H BIA method. *J Physiol Anthropol, 20 (1): 29-35, 2001* http://www.jstage.jst.go.jp/en/

Keywords: hand-to-foot bioimpedance analysis, hand-to-hand bioimpedance analysis, relative body fat, change of body posture

Introduction

In order to estimate human body composition, simple and easy methods using body density (BD) based on measurements of body segments, e.g. bioelectrical impedance analysis (BIA), skinfold method (SKF), and ultrasound method (US), have been widely used in field and clinical settings (Demura et al., 1999; Heyward and Stolarczyk, 1996). The BIA method, in which total body water and BD are estimated using the bioimpedance between the right hand and the right foot in a lying position (H-F BIA method), has been mainly used. Nevertheless, it has been reported that the bioimpedance of the H-F BIA method varies with the placement of the electrode on the dorsal surface of the hand and foot and the position of the leg and arm (Brodie, 1988). Special measurement techniques and knowledge are therefore necessary for exact measurements and the H-F BIA method is not as practical for public use as are the SKF and US methods (Brodie, 1988).

In recent years, new practical measurement-devices based on BIA, which can measure in a standing position since the electrodes are fixed on the device, have been developed (Lukaski, 1987; Baumgartner et al., 1990; Nunez et al., 1997; Tan et al., 1997; Bell et al., 1998; Utter et al., 1999; Xie et al.,1999). Consequently, it is possible for anyone to easily measure their own relative body fat (%BF) without a tester and special techniques. With regard to the BIA method, intrasubject variance of %BF is small (2–3%) (Lukaski, 1985), and the applicable sphere is wide since it can be used on people with different BD, such as children, adults, and extremely obese people. However, factors such as alteration of body water caused by posture change (Nakadomo, 1993), configuration and placement of electrodes (Graves et al., 1989; Nakadomo et al., 1991), exercise (Lukaski, 1986; Schell and Gross, 1987; Khaled et al., 1988; Nakadomo, 1990d), eating and drinking (Deurenberg et al., 1988, Gallagher et al., 1998), and menstrual cycle (Gliechauf and Rose, 1989), bring variances in the bioimpedance. Nakadomo et al. (1993) reported that the angles of the armpit and the crotch influence bioimpedance in the H-F BIA method.

Although there are studies on the BIA method in a lying position, there are few studies on a practical BIA method that can be used in a standing position. In addition, the devices for the BIA method accept original body segment induction (between hands, between feet, and between hand and foot) and a prediction equation of %BF, but their measured values have not been sufficiently compared and examined. Measured values with clinical thermometers and weighing machines are constant between different devices, but %BF with the BIA method is not always constant. The difference in measured values among the devices might cause misunderstanding or distrust of the BIA methods. It is necessary to clarify the influence of posture change, which is likely to cause an alteration of body water distribution, on %BF and the differences between different devices.

The purpose of this study was to clarify the influence of posture change on %BF in the BIA method.

Methods

Subjects

The subjects were 30 Japanese healthy young adult males aged 18 to 23 years (age: 19.8 ± 1.4 years, height: 172.3 ± 5.8 cm, weight: 67.1 ± 8.2 kg). Mean height and weight of the subjects did not differ significantly from the Japanese standard for the same age (Laboratory of Physical Education, Tokyo Metropolitan University, 1989). Prior to measurement, the purpose and procedure of this study were explained in detail and informed consent was obtained from all the subjects.

Measurement and procedure for each method

BIA method based on induction between the hand and the foot (H-F BIA): In the H-F BIA method, bioimpedance between the hand and the foot was measured with a four-terminal impedance analyzer (SIF-891, Selco, Yokohama, Japan). Two current-injector electrodes (ECG electrode, Nihon Kohden, Tokyo, Japan) with a thin Keratin electrolyte gel (Skin cleaner, Fukuda Denshi, Osaka, Japan) were positioned on the dorsal surface of the right hand and the right foot, the distal metacarpal-phalangeal and metatarsal-phalangeal, respectively. The distance between the current-introducing electrodes and the detector electrodes was maintained at 3 cm. An excitation current of 800 μA at 50 kHz was then introduced into the subject from the distal electrodes of the hand and foot. Subjects were measured in two different postures, lying on his back as the regular posture and standing as the irregular posture. In both postures, they opened both the armpits and the crotch at an angle of 30 degrees, with the arms not touching the body.

Body density was calculated using the following prediction equation for men (Nakadomo et al., 1990a), and %BF was estimated according to the formula of Brozek et al. (1963). (W: weight (kg), Z: bioimpedance (Ω), Ht: height (cm), BD: body density ($g \cdot ml^{-1}$))

$$BD = 1.1492 - 0.0918\ (W)\ (Z)/(Ht^2)$$

BIA method based on induction between both hands (H-H BIA): In the H-H BIA method, bioimpedance between both hands was measured using an HBF-300 (500 μA, 50 kHz) (Omron, Kyoto, Japan). The subjects held the device in both hands and straightened both arms forward. With individual data (age, height, and weight) input, the fat-free mass (FFM) based on its own prediction equation and %BF were calculated. Subjects were measured in two different postures, standing as the regular posture and lying on his back as the irregular posture.

Underwater weighing (UW) method: %BF estimated by the UW method was used as a criterion to examine validity in this study. Underwater weight was measured 5 times in a stainless steel water tank with a depth of 1.5 m. The subjects, after expiring maximally, sat on a chair attached to a weighing scale (AD-6204, A&D, Tokyo, Japan) with the whole body completely submerged. Water temperature was maintained at 35–37°C. Gas in the viscera was assumed to be 150 ml for all subjects. Residual volume (RV) was measured twice in a one-week period with a nitrogen washout technique (system 9, Minato Medical, Osaka, Japan) based on the open-circuit method. This measurement was carried out with the same sitting posture as the UW method.

Experimental procedure

The regular postures in the H-F BIA method and the H-H BIA method were a lying position and a standing position, respectively. In the present study, an extremely different posture from the regular posture, which was likely to cause alteration of body water distribution, was used as well as the regular posture. We set four measurement conditions, combinations of two postures at rest and two measurement postures (Fig. 1). After rest in a standing position for five minutes, the subjects were measured in a standing position (condition A). The posture was changed into a lying position and measured (condition C). Following five minutes rest in a lying position, measurements were made in a lying position (condition B) and then in a standing position (condition D). In the H-F BIA method, conditions B and C are regular posture, and conditions A and D are irregular posture. Conditions A and D are regular posture, and conditions B and C are irregular posture for the H-H BIA method. In the H-F BIA method, condition C has an extremely different posture just before measurement (standing position). If the measured values in the irregular posture are not significantly different from those in the regular posture, this implies that the posture does not need to be considered before measurement. We made two measurement orders, and assigned the subjects to the either of the measurement orders at random, in order to offset the influence of the measurement order. Five minutes of rest was determined through preliminary tests. After measuring with the BIA methods, underwater weight was measured 5 times according to the UW method. The subjects were forbidden to eat, drink, and

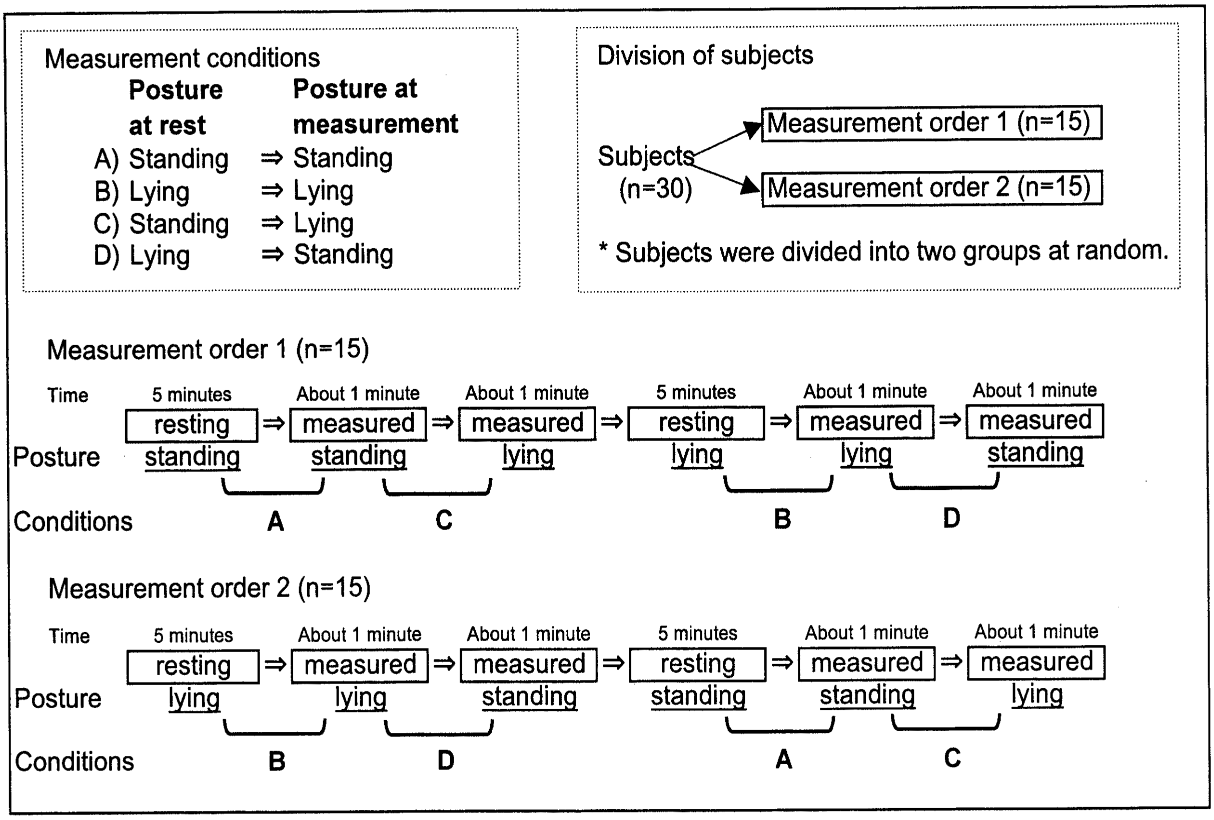

Fig. 1 Experimental procedure

exercise 2 hours before the measurement.

Statistical analysis

The intra-class correlation coefficient (ICC) was calculated to examine the reliability of RV and %BF of each BIA method and the UW method. Pearson's correlation coefficient was used to estimate a relationship between the UW method and each BIA method. The differences in %BF among the two BIA methods and the UW method and among all four measurement conditions for each BIA method were determined using one-way analysis of variance (ANOVA) for repeated measures. If there was a significant difference in the ANOVA results, Tukey's HSD was used. In this study, 5% was adopted as the level of significance.

Results

Reliability of the two BIA methods and the UW method and relationship between the methods

ICC of RV was very high (0.970). The mean of the last 3 of 5 trials was used as the data for underwater weight, according to the method of Katch and Katch (1980) and Weltman and Katch (1981). ICC of underwater weight was very high (0.997). ICC of %BF in the regular posture was very high for both BIA methods (H-H: 0.995, H-F: 0.966) (Table 1).

Table 1 Reliability of each BIA method

	Mean	SD	t-test	ICC
H-H method				
First	16.8	4.3	ns	0.995
Second	17.1	4.3		
H-F method				
First	17.3	4.0	ns	0.966
Second	17.4	4.5		

ICC: intra-class correlation coefficient. ns: not-significant.

%BF for each BIA method in the regular posture was significantly higher than that for the UW method. The correlation coefficients of %BF between the UW and the H-F BIA methods and between the UW and the H-H BIA methods were 0.767 and 0.709, respectively (Table 2). Both values were significant and not significantly different from each other ($t=0.752$, $df=27$, $p>0.05$).

The difference between measurement conditions in each BIA method

Table 3 shows the difference among the four measurement conditions in the H-F BIA method and the H-H BIA method. In the H-H BIA method, %BF for conditions C (standing position at rest and lying position at measurement) and D (lying position at rest and

Table 2 Comparison of %BF between the methods and their relationship

	Mean	SD	ANOVA	Multiple comparison HSD	Correlation with UW method	Correlation between BIA methods
H-H method	16.9	4.3			0.709*	0.795*
H-F method	17.0	4.1	8.66*	H-H,H-F>UW	0.767*	
UW method	14.6	5.9				

UW: Underwater weighing method. *p<0.05. Measurement posture was regular in both the BIA methods. There were no significant differences between the correlation coefficients of the two BIA methods with the UW method (t=0.752, df=27, p>0.05).

Table 3 Comparison of %BF among the four measurement conditions

	Posture at rest		Posture at measurement	Mean	SD	ANOVA	Multiple comparison HSD
H-H method							
A	Standing	⇒	Standing	16.8	4.3		
B	Lying	⇒	Lying	16.8	4.0	4.93*	C,D > A,B
C	Standing	⇒	Lying	17.1	4.5		
D	Lying	⇒	Standing	17.1	4.3		
H-F method							
A	Standing	⇒	Standing	16.7	4.3		
B	Lying	⇒	Lying	17.3	4.0	1.93 ns	
C	Standing	⇒	Lying	17.4	4.5		
D	Lying	⇒	Standing	17.1	4.4		

ns: non-significant. *P<0.05.

Table 4 Comparison of the difference from the %BF of the UW method among the four measurement conditions

	Posture at rest		Posture at measurement	Mean	SD	ANOVA	Multiple comparison HSD
H-H method							
A	Standing	⇒	Standing	3.7	2.9		
B	Lying	⇒	Lying	3.8	2.8	2.88*	C > A
C	Standing	⇒	Lying	4.0	2.9		
D	Lying	⇒	Standing	3.9	2.9		
H-F method							
A	Standing	⇒	Standing	4.1	2.6		
B	Lying	⇒	Lying	4.4	2.9	1.41 ns	
C	Standing	⇒	Lying	4.1	3.0		
D	Lying	⇒	Standing	4.4	3.2		

ns: non-significant. *P<0.05.

standing position at measurement) were significantly higher than conditions A (standing position at rest and standing position at measurement) and B (lying position at rest and lying position at measurement). Measured values for the conditions, including extreme posture change before measurement, were higher than those for the conditions without a posture change. Regarding the H-F BIA method, there were no significant differences among the four measurement conditions.

We calculated the difference in %BF between each BIA method and the UW method for every measurement condition, and compared the difference among the four measurement conditions. In the H-H BIA method, the difference in condition C, in which the regular posture was changed into an irregular posture just before measurement, was significantly higher than that in condition A, in which the regular posture was not changed just before measurement. In the H-F BIA, there were no significant differences among the four measurement conditions (Table 4).

Discussion

Validity and reliability of the BIA methods

In the H-F BIA method, %BF was estimated using BD, which was calculated using bioimpedance. In the H-H BIA method, %BF was estimated using fat-free mass, which was also calculated using bioimpedance. Although the two methods use a different process to estimate %BF, their reliabilities are considered to be high, agreeing with a previous study (Yoshimura, 1997). We used %BF based on the UW method as a criterion of validity. The following values have been used as the data in the UW method; mean of 5 trials (Morrow et al., 1986), mean of the last 2 or 3 trials in multiple trials (Katch and Katch, 1980; Weltman and Katch, 1981), maximum (Wagner and Heyward, 1999), and mean of 3 trials meeting the condition that their differences are less than 100 g (Wagner and Heyward, 1999). We used the mean of the last 3 trials following the method of Katch and Katch (1980). The difference among the 3 trials was less than 100 g, therefore, the condition of Wagner and Heyward (1999) was also met.

The reliabilities of underwater weight and RV were similar to or higher than those of the previous studies (Marks and Katch, 1986; Morrow et al., 1986), so that it was correct to use %BF based on the UW method as a criterion to examine validity of the BIA methods. The reliabilities of both BIA methods were also similar to or higher than those of the previous studies (Yoshimura et al., 1997; Demura et al., 1999). There is no agreement on the validity of %BF of the BIA method when using %BF based on the UW method as a criterion. Namely, both underestimating (Nakadomo et al., 1990a, 1990b) and overestimating (Keller and Katch, 1986; Hodgdo and Fitzgerald, 1987) have been reported. In the present study, %BF of the BIA methods tended to be overestimated by about 2%-3% on average. Some researchers have reported that the relationship between the UW method and the H-F BIA method was mid-range or more (r=0.64–0.95) (Keller et al., 1986; Shore et al., 1986; Schell et al., 1987; Jackson et al., 1988; Nakadomo et al., 1990a; Nakadomo et al., 1991; Yoshimura et al., 1997). Yoshimura et al. (1997) reported that the relationship between the UW method and the H-H BIA method was high (male: r=0.95, female: r=0.90). In the present study, the relationship between the UW method and each BIA method was mid-range (H-F: r=0.767, H-H: r=0.709), which are not different from the results of the previous studies.

Judging from the above, the reliability and the validity of the BIA methods selected in this study may be guaranteed.

The influence of posture change on %BF in the BIA methods

Although the H-F BIA method has been used as a typical BIA method, it has several faults: it needs a tester familiar with the measurement and a relatively long time to measure, and subject has to lie on his back, which is troublesome. The H-H BIA method, however, does not have these faults and hence is a practical method. In all the BIA methods, it is supposed that the distribution of body water and electrolytic matter, which can pass an electric current easily, causes a variance of bioimpedance, as does the amount of body water and electrolytic matter (Heyward and Stolarczyk, 1999). The H-H BIA method might be especially influenced by the alteration of body water caused by the posture change because of more localized bioimpedance (between both hands). Nakadomo et al. (1990d) reported that there are no significant differences in the bioimpedance among different postures; lying position, sitting position, and standing position, in the H-F BIA method. We compared %BF among four measurement conditions, considering not only the difference of posture at measurement but also the posture change before measurement. The distribution and amount of body water bring a variance of bioimpedance (Heyward and Stolarczyk, 1996). Sufficient time was allocated for rest in order to steady the distribution of body water that was influenced by the posture change, but there were no significant differences in %BF among the measurement conditions in the H-F BIA method. In addition, all relationships in %BF between the four measurement conditions were very high, and the relationship in %BF between the UW method and every condition was mid-range. Consequently, a posture change just before measurement may not influence the variance of %BF in the H-F BIA method. The H-F BIA method might be more precise since an electric current is sent between the hand and the foot, and the %BF is under more influence of the water and fat of the whole body compared to the H-H BIA method. In the H-F BIA method, the measured values in the irregular posture, or standing position, were not different from those in the regular posture, or lying position. This indicates the possibility of using a practical standing posture.

In this study, subjects opened both armpits and the crotch at an angle of thirty degrees for all measurement conditions in the H-F BIA method. Nakadomo et al. (1993) reported that differences in the armpit angle and the crotch angle bring a variance in %BF because of the shortened conduction path by contact with the body and between the legs. It is necessary to confirm the difference in %BF among different angles of the armpits and the crotch. %BF may, however, be not greatly influenced when the arms are not touching the body and both legs are separated, even though the posture is irregular or changed just before measurement.

It has been reported that the validity and reliability of the H-H BIA method is high (Yoshimura et al., 1997). A difference in measured value was found only in cases where the posture was extremely changed just before measurement: from a standing position into a lying position and from a lying position into a standing position. This suggests that the posture change just before measurement influences %BF more than irregular posture in the H-H BIA method. Patterson (1989) found that measured values in the H-F BIA method reflects resistance of the arm, namely, about 1/2-2/3 of total bioimpedance depends on the arm. Yoshimura et al. (1997) inferred that the H-F BIA method and the H-H BIA method are similar in body parts where an electric current passes through, although the measurement parts of body are different. The result in this study indicates that %BF of the H-F BIA and H-H BIA methods are similar regardless of the difference of measurement posture.

As for the H-H BIA method, the measured value varied when the measurement posture was changed just before measurement. The distance between body parts where an electric current passes through in the H-H BIA method is shorter than in the H-F BIA method, therefore, %BF of the H-H BIA method may be easily influenced by the alteration of body water distribution. When estimating the %BF using the H-H BIA method, it is necessary to pay attention to the posture change just before measurement.

Conclusions

The reliability of %BF in the H-H BIA and H-F BIA methods was very high, and the relationship in %BF between the UW method and each BIA method was mid-range. In the H-F BIA method, there were no differences in %BF among different measurement postures. This suggests that %BF is little influenced by the irregular posture and the posture change just before measurement. In the H-H BIA method, %BF increased significantly when the posture was changed just before measurement. It may be necessary to pay attention to the posture change just before measurement when using the H-H BIA method.

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Received: July 12, 2000
Accepted: October 30, 2000
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