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Full Length Research Paper

Estimation of segmental fat free mass in Taiwanese elderly females by bioelectrical impedance analysis with new mathematical model

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The aim of this study was to develop new predictive equations for evaluating the fat free mass (FFM) of body segments in Taiwan elderly female. Modified bioelectrical impedance analysis with eight electrodes (BIA_8) and referenced standard dual-energy x-ray absorptiometry (DXA) was applied to measure the segment body composition. The criterion of FFM values determined by DXA and predictive values by BIA were compared. After analyzing by linear regression, we obtained the FFM predictive equations by BIA_8 for segments. The Bland-Altman analysis was used to evaluate the differences of mean estimated segmental FFM from equations by BIA_8 and by DXA. The correlation coefficient (R) of FFM between values measured by DXA and estimated by BIA_8 in whole body, lower limbs, upper limbs and trunk were 0.89, 0.64, 0.60 and 0.81, respectively, and the differences of mean FFM were 2.39, 0.94, 0.27 and 2.02 kg, respectively. With the relatively higher weight coefficient of H^2/Z (H, height; Z, impedance values), it plays a critical role in our new predictive equation. For the greater performance in prediction of fat free mass by our new BIA model, it provides potential in monitoring the body composition in female elderly by greater precision way.

Key words: Dual-energy x-ray absorptiometry (DXA), prediction equation, body composition.

INTRODUCTION

Body composition is one of the most important indicators for evaluating the human nutritional status and health fitness. This index is highly related to the mortality and morbidity, especially in the elderly (Gale et al., 2006; Sayer et al., 2007). Changes in body composition occurs with progress in aging, specifically a decrease in fat free mass (FFM) (Borkan et al., 1983; Evans and Campbell, 1993) and an increase in fat mass (FM) (Evans and the operation of monitoring the diseases risks, mal-Campbell, 1993; Movak, 1972; Noppa et al., 1979). For nutrition status and physical status in clinical application, the important issues about the evaluation of elderly body composition should be addressed (Kuczmarski, 1989).

At present, applications for evaluating the body composition, methods such as air-displacement plethysmography, bioelectrical impedance analysis (BIA), computed tomography (CT), dual-energy x-ray absorptiometry (DXA), magnetic resonance imaging, underwater weighing, and neutron activation analysis dilution methods have been developed (Ellis, 2001). There are more or less limitations and merits in each of the aforementioned methods while assessing body composition. The advantages of BIA have been compensated

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Table 1. Anthropometric and body composition indices of the study population.

Parameter	Female (n = 30)		
	Mean	SD	Range
Age (year)	61.6	5.6	55.2 - 74.8
Height (cm)	155.9	6.8	142.5 - 176.0
Weight (kg)	62.7	10.0	42.0 - 82.1
BMI (kg/m^2)	25.8	3.8	17.9 - 36.5
$FM_{whole\text{-}DXA}$*(%)	41.3	6.3	26.0 - 50.8
$FM_{low\text{-}DXA}$ *(%)	37.5	7.7	23.0 - 51.3
$FM_{upper\text{-}DXA}$ *(%)	40.1	6.7	22.6 - 52.2
$FM_{trunk\text{-}DXA}$ *(%)	45.1	7.0	26.0 - 55.2

*Whole body fat percentage measured by DXA.

by a less precision in estimating body composition compared with DXA and other reference methods (Huang et al., 2000). However, for the immobilization in elderly with chronic diseases in hospital and home-care unit, the easy operation, non-invasive, portable, no health risk to volunteers and fast evaluation characteristics in BIA estimation of body composition have rendered it a feasible application (Roubenoff et al., 1997; Kyle et al., 2004). However, as to commercial applications, the formal validation and verification of built-in predictive estimation equations in commercial BIA have not been academically and publicly checked. In addition, the specific suitability in the evaluation of body composition for each cohort was still challenged. The applicable utility of BIA was limited by the reliable validity, especially challenged in clinical usage (Lukaski and Siders, 2003).

Nowadays, whole body FFM, body fat percentage, total body weight and intercellular fluid are evaluated by using prevalent foot to hand BIA measurement. However, the requirement of clinical application on segmental estimation of body composition for evaluating nutritional status and health fitness increases day after day. Organ et al. (1994) developed the theory and application for the segmental BIA with octa-electrodes (Bracco et al., 1996). In addition, BIA measurement with octa-electrodes in a standing posture was widely explored by academic researches (Bedogni et al., 2003; Jaffrin and Morel, 2009; Stewart et al., 1993; Zhu et al., 1998). The octa-electrodes instrument in a standing posture was applied for commercial and clinical instruments for its characteristics of easy use (Gibson et al., 2008; Pietrobelli et al., 2004; Prins et al., 2008; Sato et al., 2007). Hence, instead of whole body estimation, the measurement of segmental FFM by the gold standard, DXA, can be used as reference to validate the segmental BIA estimation in a standing posture for improving the accuracy.

The validity of the estimation of whole body composition by BIA in specific cohort has been accomplished (Bosy-Westphal et al., 2008). The estimation of whole body composition in the elderly by commercial tetra-electrodes or octa-electrodes BIA measurements have also been explored (Mally et al., 2011; Mitsui et al., 2006). The prediction equations determined in younger populations did overestimate FFM in elderly subjects not only in male but also in female by 1 to 6 kg (Deurenberg et al., 1990). The correlations and deviations between determined regional FFM by DXA and estimated regional FFM by our created estimation equations derived from modified octa-electrodes BIA in standing posture were verified (Hsieh et al., 2011). However, different population showed specific estimation equation, especially in athlete, elderly and for gender (Roubenoff et al., 1997; Svantesson et al., 2008). Estimation equations for FFM in whole body, lower limbs, upper limbs and trunk in health female elderly by modified octa-electrodes BIA (BIA_8) in standing posture were developed in this study.

MATERIALS AND METHODS

Subjects

Taiwan elderly female over 55 years old, which carried no chronic diseases such as artificial heart, cancers, chronic pulmonary diseases, diabetes mellitus, hepatitis relative diseases, hypertension, implanted steel nail, nephritic syndrome, and any artificially electrical implantation, were recruited under the formal permission of Institutional Review Board (IRB) of Advisory Committee at Jen-Ai Hospital of Taiwan. 30 elderly females were fully informed about the details of method and steps to obtain the formal consents from them. The consumption of alcohol for two days and administration of diuretics for seven days were restricted before the proposed experiments. The basic subject's characteristics are shown in Table 1.

The measurement of octa-electrodes BIA instrument

The BIA instrument, with independent detection electrodes and current source electrodes in platform embedded with tetra-polar electrodes and griped handle embedded with bi-polar electrodes, can create different circuits to measure the BIA values in corresponding segments by switching measuring models (Organ et al., 1994). The modified BIA instrument designed by ourselves was termed as BIA_8. The QuadScan 4000 (Bodystat Corp., U.K.), connected with computer was operated by the current at 400 μA

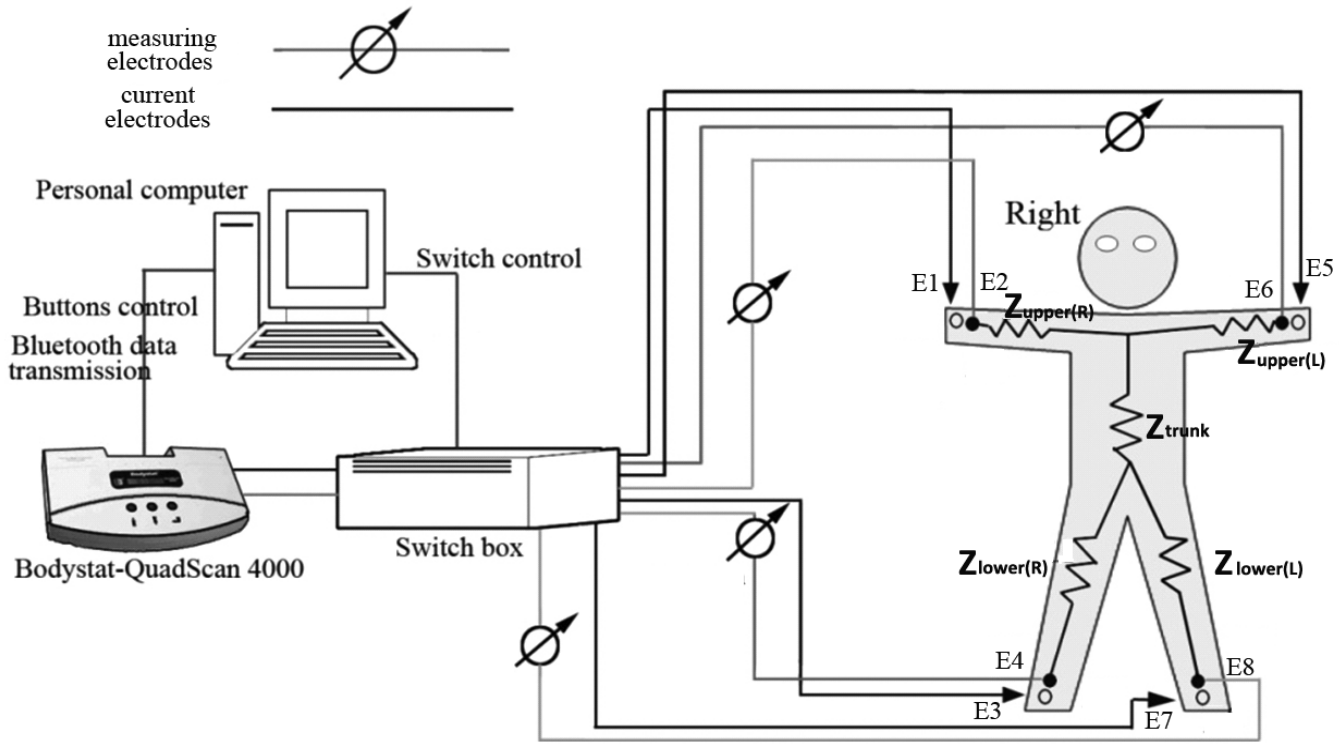

Figure 1. The modified BIA instrument with eight electrodes (BIA_8). In the circuit between E1 and E3, the measurement between E2 and E4 can obtain the Z_{whole}; in the circuit between E1 and E3, the measurement between E4 and E8 can obtain the $Z_{lower(R)}$; in the circuit between E5 and E7, the measurement between E4 and E8 can obtain the $Z_{lower(L)}$; in the circuit between E1 and E3, the measurement between E2 and E6 can obtain the $Z_{upper(R)}$; in circuit between E5 and E7 with the measurement between E2 and E6 can obtain the $Z_{upper(L)}$; in circuit between E1 and E3 with the measurement between E6 and E8, Z_{trunk} can be obtained. $Z_{whole} = Z_{upper(R)} + Z_{lower(R)} + Z_{trunk}$

with frequency at 50 KHz during measurement. The electronic impedance between two electrodes was much greater than bioelectronics' impedance. To confirm the stability of accuracy and precision as original instrument after modification, data from the prior test and post test were verified carefully. As shown in Figure 1, the E1, E3, E5 and E7 were current electrodes and E2, E4, E6 and E8 were measuring electrodes. All the electrodes were made of stainless steel with high conductivity. E1, E2, E5 and E6 were placed on the handle and on a platform. The bioelectrical impedance value (Z) yielded in each human segment was termed as followed: $Z_{upper(R)}$ as Z value of right upper limb, $Z_{upper(L)}$ as Z value of left upper limb, Z_{trunk} as Z value of trunk, $Z_{lower(R)}$ as Z value of right lower limb and $Z_{lower(L)}$ as Z value of left lower limb. The summation of $Z_{upper(R)}$, Z_{trunk}, and $Z_{lower(R)}$ created the total body impedance as Z_{whole}. The circuit between E1 and E3 with the measurement between E2 and E4 can obtain the Z_{whole}, as well as that of E4 and E8 the $Z_{lower(R)}$. The circuit between E5 and E7 with the measurement between E4 and E8 can obtain the $Z_{lower(L)}$ as well as that of with E2 and E6; the $Z_{upper(L)}$. The bioelectric impedance value of each body segment measured by QuadScan 4000 combined with age, body height and segments weight was used to develop predictive equation for body composition.

The determination of body composition by DXA

Body weights were determined within the error at 0.1 kg and body heights at 0.5 cm. Subjects in standard cotton dress without any metal attachment were scanned ove r whole body by DXA (Dual energy x-ray absorptiometry, Lunar Prodigy, GE Corp, USA.) and then analyzed by the software enCore 2003 Version 7.0. The FFM, total body fat (BF), and bone mineral density were subsequently computerized and quantified. The scanning protocol was operated at 20 μGy in 20 min by legally registered and well trained medical technologists in the Department of Radiology, Dah Li County Jen-Ai Hospital in Taiwan.

Statistical analysis

All the experimental data were analyzed by SPSS software (version 12.0, SPSS Inc., Chicago, IL, USA). Results were expressed as mean ± SD (standard deviation). R values obtained from linear regression analysis and Pearson's were presented to describe the correlation between any variability. We followed the program suggested by Bland and Altman (1986) to survey the variability and distributions between segmental FFM values estimated by the aforementioned correlation equations vs. segmental FFM values measured by whole body DXA. A confidence level of 5% ($p < 0.05$) was considered as significant. By using the linear regression analysis with parameters such as height, weight, age and relative BIA values, the linear functional equations for predictions of FFM in whole body, lower limbs, upper limbs and trunk can be obtained.

RESULTS

The mean age, height, body weight, and BMI (body mass

Table 2. Coefficients of linear regression equations of segments FFM measured by DXA and estimated by BIA_8.

Item	Female		
	R*	Slope	Intercept
Whole body	0.89	0.69	10.88
Lower limb	0.64	0.38	2.16
Upper limb	0.60	0.35	1.07
Trunk	0.83	0.88	5.67

*R were the correlation of linear regression equation for corresponding items

index) of 30 subjects were 61.6 ± 5.6 years old, 155.9 ± 6.8 cm, 62.7 ± 10.0 kg and 25.8 ± 3.8 kg/m^2, respectively (Table 1). The mean value of BF measured by DXA was 41.3 ± 6.3% (Table 1). The segmental Z values combined with age, body height and segment weights were used to develop our estimation equation for segmental body composition. The FFM of whole body, trunk, lower limbs, and upper limbs was termed as $FFM_{whole\text{-}DXA}$, $FFM_{trunk\text{-}DXA}$, $FFM_{lower\text{-}DXA}$, and $FFM_{upper\text{-}DXA}$. The whole body FFM estimated by BIA_8 was termed as $FFM_{whole\text{-}BIA}$, the trunk as $FFM_{trunk\text{-}BIA}$, the lower limbs as $FFM_{lower\text{-}BIA}$, and upper limbs as $FFM_{upper\text{-}BIA}$. The estimation Equations (Eq.) of $FFM_{whole\text{-}BIA}$, $FFM_{lower\text{-}BIA}$, $FFM_{upper\text{-}BIA}$, and $FFM_{trunk\text{-}BIA}$ were derived as (1), (2), (3) and (4), respectively. The $FFM_{trunk\text{-}BIA}$ could be the difference of $FFM_{whole\text{-}BIA}$ minus $FFM_{lower\text{-}BIA(R)}$, $FFM_{lower\text{-}BIA(L)}$, $FFM_{upper\text{-}BIA(L)}$ and $FFM_{upper\text{-}BIA}$ and was described as (4').

$$FFM_{whole\text{-}BIA} = 17.283 + 0.543\ H^2 / Z_{whole} + 0.181\ W - 0.200\ Y$$
(R = 0.89, SEE= 2.63 kg, $p < 0.01$, n = 30) (1)

$$FFM_{lower\text{-}BIA} = 2.915 + 0.031\ H^2 / Z_{lower} + 0.024\ W - 0.023\ Y$$
(R = 0.64, SEE = 0.68 kg, $p < 0.01$, n = 60) (2)

$$FFM_{upper\text{-}BIA} = 0.478 + 0.014\ H^2 / Z_{upper} + 0.010\ W - 0.006\ Y$$
(R = 0.60, SEE= 0.27 kg, $p < 0.01$, n = 60) (3)

$$FFM_{trunk\text{-}BIA} = 10.237 + 0.001\ H^2 / Z_{trunk} + 0.213\ W - 0.107\ Y$$
(R = 0.72, SEE = 2.15 kg, $p < 0.01$, n = 30) (4)

$$FFM_{trunk\text{-}BIA} = FFM_{whole\text{-}BIA} - FFM_{lower\text{-}BIA\ (R)} - FFM_{lower\text{-}BIA\ (L)} - FFM_{upper\text{-}BIA\ (R)} - FFM_{upper\text{-}BIA\ (L)}$$
(R = 0.81, SEE = 1.77 kg, $p < 0.01$, n = 30) (4')

Where H, is the body height (cm); W, is the body weight (kg); Y, is the age (years); Z, is the bioelectrical impedance (ohm); FFM, is the fat free mass (kg); SEE, is the standard error of estimation (kg).

The intercept, slope, SD and correlation coefficient for FFM_{upper}, FFM_{lower} and FFM_{whole} measured by DXA and BIA are illustrated in Table 2. The correlation coefficient of measured $FFM_{whole\text{-}DXA}$ and our developed Equation (1) was 0.89. The correlation coefficients for $FFM_{lower\ limb\text{-}DXA}$, $FFM_{upper\ limb\text{-}DXA}$, and $FFM_{trunk\text{-}DXA}$ between our Equations (2), (3), and (4) were 0.64, 0.60 and 0.72, respectively. After being elucidated by Bland and Altman adopted program, the distributions of variability between FFM estimated from aforementioned correlation equations by BIA_8 *vs.* FFM measured by DXA are shown (Figure 2). The estimated $FFM_{whole\text{-}BIA}$ by Equation (1), $FFM_{trunk\text{-}BIA}$ by Equation (2), $FFM_{lower\ limb\text{-}BIA}$ by Equation (3) and $FFM_{upper\ limb\text{-}BIA}$ by Equation (4) vs. measured $FFM_{whole\text{-}DXA}$, $FFM_{trunk\text{-}DXA}$ $FFM_{lower\ limb\text{-}DXA}$, and $FFM_{upper\ limb\text{-}DXA}$ are shown in Figure 2a to d, respectively.

To elucidate whether the impedance index – (H^2/Z) were important in predictive equation, the analytical results of the measured H^2/Z values by BIA_8 and measured FFM by DXA in whole body and multiple segments are listed in Table 3. The coefficient of constant, H^2/Z_{whole}, W parameter and Y parameter in Equation (1) were evaluated to obtain the $FFM_{whole\text{-}BIA}$ evaluation equation as 17.283, 0.543, 0.181 and -0.200 while the H^2/Z_{whole}, W and Y (as average at 38.0 cm^2/ohm, 62.7 kg and 61.6 years), respectively were imputed into our estimation equation to obtain the FFM as 19.6 Kg. The weight coefficients for the estimation of FFM as 104.9, 58.3 and -62.7%, respectively, indicated that the H^2/Z_{whole} is the crucial one. Similarly, the H^2/Z_{lower} in Equation (2) was estimated as 97.1%, the H^2/Z_{upper} in Equation (3) as 78.6% and the H^2/Z_{trunk} in Equation (4) as 14.0%. We obtained the estimation equation with greater perfor-mance in prediction of FFM in upper limbs, lower limbs and trunk as -0.07 ± 2.39, 0.04 ± 0.94, -0.05 ± 0.27 and 3.31 ± 2.02 kg than with the results measured by the instrument Tanita BC-418 (Tanita Co., Tokyo, Japan) as 1.84 ± 3.13, 0.68 ± 1.33, -0.62 ± 0.95 and 3.70 ± 2.84 kg (Pietrobelli et al., 2004).

DISCUSSION

The body height between arm segments exist as high correlation coefficient (R = 0.97-0.98) (Jarzem and Gledhill, 1993); correspondingly, we can well presume body height as constant for all segments. Notably, the application of height rather than upper or lower limb length in this study was more feasible for establishing

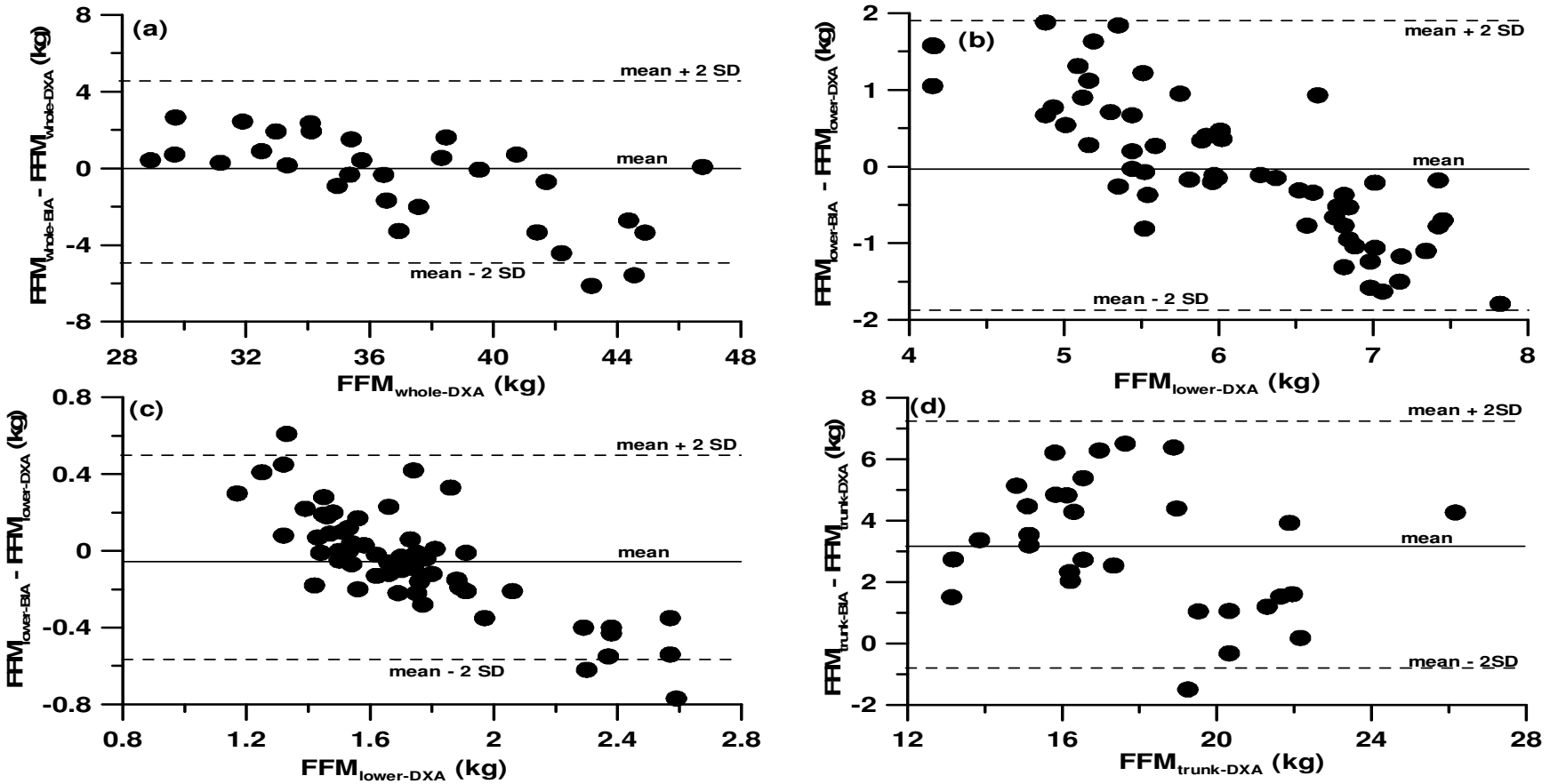

Figure 2. The distribution plot of differences in the estimated FFM from Equation (1) to (4) by BIA *vs.* measured FFM by DXA. (a) Fat free mass in whole body (mean= 0.0 kg, SD = 2.39 kg, mean – 2SD = -4.78 kg, mean – 2 SD = 4.78 kg). $FFM_{whole\text{-}BIA}$ = 17.283 + 0.543 H^2 / Z_{whole} + 0.181 W – 0.200 Y, (R = 0.89, SEE= 2.63 kg, $p < 0.01$, n = 30). (b) Fat free mass in lower limbs (mean= 0.0 kg, SD= 0.94 kg, mean - 2SD = -1.88 kg, mean + 2 SD = 1.88 kg). $FFM_{lower\text{-}BIA}$= 2.915 + 0.031 H^2 / Z_{lower} + 0.024 W – 0.023 Y, (R = 0.64, SEE = 0.68 kg, $p < 0.01$, n = 60). (c) Fat free mass in upper limbs (mean = 0.0 kg, SD = 0.27 kg, mean - 2SD = -0.54 kg, mean + 2 SD = 0.54 kg). $FFM_{upper\text{-}BIA}$ = 0.478 + 0.014 H^2 / Z_{upper} + 0.010 W - 0.006 Y, (R = 0.60, SEE = 0.27 kg, $p < 0.01$, n = 60). (d) Fat free mass in trunk (mean = 3.31 kg, SD = 2.02 kg, mean - 2SD = -0.73 kg, mean+ 2 SD = 7.35 kg). $FFM_{trunk\text{-}BIA}$ = 10.237 + 0.001 H^2 / Z_{trunk} + 0.213 W – 0.107Y, (R = 0.72, SEE = 2.15 kg, $p < 0.01$, n = 30).

segmental FFM equation and operational analysis. It was well known that the BIA values of human body between with true lean body mass or so called fat free mass exist in high correlation (de Lorenzo et al., 1998), which can provide the great rationale for estimating human body composition. In many studies, the H^2/z_{whole} was often used as the major input independent variables. We did take the H^2/Z_{whole} in our Equation (1) for estimated FFM_{whole}. Likewise, H^2/Z_{lower} in Equation (2) was for $FFM_{lower\text{-}BIA}$, H^2/Z_{upper} in Equation (3) was for $FFM_{upper\text{-}BIA}$, and H^2/Z_{trunk} in Equation (4) was for $FFM_{trunk\text{-}BIA}$, respectively. To obtain each segmental FFM evaluation equations, segmental H^2/Z, W, and Y with DEX standard value were

Table 3. The measured H^2/Z values by BIA_8 and measured FFM by DXA in whole body and multiple segments.

Item	Female (n = 30)		
	Mean	SD	Range
$FFM_{whole\text{-}DXA}$	37.12	4.95	28.91 - 46.76
$FFM_{trunk\text{-}DXA}$	17.81	3.11	13.14 - 26.17
$FFM_{lower(R)\text{-}DXA}$*	6.13	0.88	4.15 - 7.63
$FFM_{lower(L)\text{-}DXA}$	6.09	0.87	4.16 - 7.82
$FFM_{upper(R)\text{-}DXA}$	1.75	0.34	1.32 - 2.59
$FFM_{upper(L)\text{-}DXA}$	1.73	0.35	1.17 - 2.57
Z_{whole}	641.7	66.8	465.0 - 777.0
$Z_{lower(R)}$	253.5	34.2	192.0 - 351.0
Z_{trunk}	26.6	14.9	6.0 - 91.0
$Z_{lower(L)}$	250.0	35.7	182.0 - 343.7
$Z_{upper(R)}$	361.3	43.6	263.0 - 477.0
$Z_{upper(L)}$	364.6	41.2	262.0 - 462.0
H^2/ Z_{whole}	38.0	4.5	20.1 - 48.4
H^2/ Z_{trunk}	1103.4	714.7	274.3 - 4320.2
H^2/ Z_{lower}	96.2	14.9	65.9 - 134.2
H^2/ Z_{upper}	67.9	8.9	49.1 - 92.4

*The $FFM_{trunk\text{-}DXA}$ value contained head segment. FFM were in kg, Z in ohm, H^2/Z in cm^2/ohm.

imputed and analyzed by linear regression analysis. It was showed that the length square dividing bio-electronic impedances values (H^2/Z) was a major parameter in the present BIA_8 measurements, since the major weight parameter of an equation shows greater weight coefficient in the equation.

The estimated $FFM_{lower\text{-}BIA}$ and $FFM_{upper\text{-}BIA}$ were correlated (R = 0.66 and 0.60, respectively) with the determined FFM by DXA. The estimated FFM_{trunk} were highly correlated with determined FFM by DXA. As shown in Figure 2(a) and Table 3, the relative lower difference (as SD = 2.39 kg), as well as high correlation coefficient (R = 0.89), existed between estimated $FFM_{whole\text{-}BIA}$ by our BIA_8 and determined $FFM_{whole\text{-}DXA}$. The result of high correlation coefficient of $FFM_{whole\text{-}BIA}$ between by our BIA_8 and determined $FFM_{whole\text{-}DXA}$ is in agreement with the results of Genton et al. (2001), Roubenoff et al. (1997), Baumgartner et al. (1991) and Deurenberg et al. (1990). In spite of minor difference in our study and that of Genton et al. (2001), the correlations and SD in FFM_{whole} were similar. In addition, the relative higher differences and lower correlation coefficients existed between estimated lower limb FFM by anthropometric method and by DXA in Rugby Union players (Bell et al., 2000), compared to the results from our study.

To obtain $FFM_{trunk\text{-}BIA}$, H^2/Z_{trunk}, W and Y with DXA standard value was input and analyzed by linear regression analysis; was one way [Equation (4)]. Subtracted $FFM_{lower\text{-}BIA}$ and $FFM_{upper\text{-}BIA}$ from $FFM_{whole\text{-}BIA}$ was the other way [Equation (4')]. The obtained $FFM_{trunk\text{-}BIA}$ from Equation (4) or from Equation (4') should contain the FFM of head. The bioelectric impedance value in trunk as Z_{trunk} detected by the circuit between E1 and E3 with the measurement between E6 and E8 was about 26.6 ± 14.9 ohms. The greater SD value of Z_{trunk} may attribute to the more complex content as organs and larger cross-sectional area. Equation (4) exhibited lower correlation coefficient and greater SD than Equation (4'). To elucidate the contributing factors of variables as H^2/Z_{whole}, W and Y in the estimation equation, H^2/Z_{whole} exhibited the highest contribution. It indicates that the H^2/Z_{whole} is the crucial factor in Equation (1) and this is in agreement with the application in Lukaski's publication (Lukaski et al., 1985). Similarly, the highest contributing factors of H^2/Z_{whole} than that of W and Y can also be observed in Equations (2) and (3).

The estimated FM_{trunk} value, which contains the viscera fat and abdominal subcutaneous adipose, can be an applicable index for surveying the health status. Besides, the evidences from epidemiological surveillance showed that intra-abdominal fat is strongly relative to metabolic syndrome (Fujioka et al., 1987; Seidell et al., 1990). Although the $FFM_{lower\text{-}BIA}$ and $FFM_{upper\text{-}BIA}$ were not our major concern, they can also contribute to promoting the greater performance in prediction of FFM_{trunk}. The $FFM_{trunk\text{-}BIA}$ from Equation (4') was derived by $FFM_{whole\text{-}BIA}$ subtraction from $FFM_{lower\text{-}BIA}$ and $FFM_{upper\text{-}BIA}$ and that from Equation (4) were directly derived by $FFM_{trunk\text{-}BIA}$. For the sake of greater precision existing in the estimated $FFM_{trunk\text{-}BIA}$ from Equation (4') than from Equation (4), we adopted the estimated FFM_{trunk} from Equation (4'). While our results compared to the most popular commercial instrument, the greater performance in prediction of FFM in upper limbs, lower limbs and trunk in our created

equations were more than that in the built-in function of Tanita BC-418 (Tanita Co., Tokyo, Japan) (Pietrobelli et al. 2004).

Conclusion

The low difference mean and high correlation coefficient that existed by our modified BIA_8 instrument indicate the feasiable application for body composition monitoring instrument in elderly female, especiallly for evaluating health status by FFM_{trunk}.

Abbreviations:

FFM, Fat free mass; **BIA**, bioelectrical impedance analysis; **DXA**, dual-energy x-ray absorptiometry; **BIA_8**, 8 electrodes; **R**, correlation coefficient; **H^2**, height square; **Z**, impedance value; **E1**, **E3**, **E5**, **E7**, current electrodes; **E2**, **E4**, **E6**, **E8**, measuring electrodes; **$Z_{upper(R)}$**, Z value of right upper limb; **$Z_{upper(L)}$**, Z value of left upper limb; **Z_{trunk}**, Z value of trunk; **$Z_{lower(R)}$**, Z value of right lower limb; **$Z_{lower(L)}$**, Z value of left lower limb; **Z_{whole}**, total body impedance; **FFM_{whole}**-DXA, whole body FFM measured by DXA; **FFM_{trunk}**-DXA, trunk **FFM** measured by DXA; **FFM_{lower}**-DXA, lower limbs FFM measured by DXA; **FFM_{upper}**-DXA, upper limbs FFM measured by DXA; **FFM_{whole}**-BIA, whole body FFM estimated by BIA_8; $FFM_{trunk-BIA}$, trunk FFM estimated by BIA_8; $FFM_{lower-BIA}$, lower limbs FFM estimated by BIA_8; **FFM_{upper}**-BIA, upper limbs FFM estimated by BIA_8; H, body height; W, body weight; Y, age; **SEE**, standard error of estimation; **SD**, standard deviation; **BMI**, body mass index; **BF**, total body fat.

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