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Original Article

Can bioelectric impedance monitors be used to accurately estimate body fat in Chinese adults?

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Many laboratory-based methods exist to estimate body fat, yet few can be rapidly and easily applied to field studies. Bioelectric impedance analysis (BIA) has developed to include portable foot-to-foot systems that can estimate body fat during field studies, but it is unclear if the data they provide are comparable to anthropometric methods traditionally used in large epidemiological fieldwork. This study analysed the reliability and validity of three BIA devices (low, medium, and high cost), from duplicate measures of mass and percentage body fat (%BF) from 20 young Chinese. Comparisons were made to reference values of %BF derived from 38 duplicated anthropometric measurements and the mean of at least 7 regression equations. All three BIA devices were reliable, with intraclass correlation coefficients never below 0.999, whilst both technical errors of measurement and coefficients of variation (expressed as percentages) were below 1%. Validity analysis revealed all three devices significantly overestimated %BF using the standard measurement setting (no correction for athletic status) compared to the reference method: UM-022 (+3.2%, $p< 0.01$), BF-350 (+2.6%, $p< 0.01$), and TBF-410 (+2.1%, $p< 0.01$). When %BF was corrected for athletic status, neither the BF-350 (+0.3%, $p= 0.72$), nor the TBF-410 (-0.2%, $p= 0.86$) produced a %BF that differed significantly from the reference method. It was concluded that these three BIA devices were reliable and could be recommended as valid field measures of mass and %BF in this sample population provided the device allows a correction for athletic status.

Key Words: validity, reliability, body composition, bioelectric impedance analysis

Introduction

Gathering valid and reliable information on an individual's body composition is of considerable interest to health professionals such as nutritionists and epidemiologists, as it is viewed as a strong predictor of human mortality and morbidity.[1] Having a valid surveillance measure of body composition is also essential for monitoring the prevalence of obesity, as this has become a major public health problem in many developed and developing nations,[2, 3] especially that of China.[4] Although one of the best methods for determining body composition is the 4-component model,[5-7] neither it, nor other techniques such as dual-energy X-ray absorptiometry (DEXA), or densitometry, can be applied outside the research laboratory. For routine public health assessment and for large-scale epidemiological studies, valid and reliable field measures of body fat are required that are safe, cheap, portable, ethically acceptable and can be operated by assistants without detailed training. One technique that appears to satisfy many of these requirements is that of bioelectric impedance analysis (BIA).

Although early BIA devices were used primarily to estimate total body water, subsequent developments led to their use in human body composition analysis,[8] but these often required the careful attachment of tetrapolar electrodes to the extremities whilst the subject lay supine for several minutes.[9, 10] Subsequent developments have lead to portable bipolar BIA devices that can be used rapidly with subjects either standing on footplates (foot-to-foot impedance),[6, 11] using hand-held devices,[12] or most recently, multi-limb systems.[13] However, before these BIA devices can be routinely used as a tool to aid public health assessment or in large epidemiological studies, there is a need to check their population-specific accuracy in estimating body composition,[14-16] and to examine the influence of different levels of habitual physical activity on foot-to-foot BIA technology,[17] as some devices allow the user to select either a standard or athletic mode.

The purpose of this study was to investigate the validity and reliability of three bipolar foot-to-foot BIA devices (Tanita models: UM-022, BF-350, and TBF-410) for measuring body mass and body fat when compared to more traditional reference methods: A&D UC300 weighing scales and a detailed anthropometric model, respectively. The three Tanita models were chosen as they represent devices that span low cost (~US$80; UM-022), medium cost (~US$500; BF-350), and high cost (~US$2,000; TBF-410), as this would provide an end-user with a range of options most suited to their budgets. If the BIA devices

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were shown to be both reliable and valid, the possibility existed for them to be used to replace the traditional, and more time-consuming, anthropometric methods in assessing levels of body fat in large field studies. Using BIA devices also avoids many of the cultural and gender difficulties associated with traditional epidemiological measurements of girths and skinfold thickness.

Methods

Subjects

A total of 20 young Chinese adults (10 males), aged 19 to 30 years volunteered to participate in this study. All were full-time students at The University of Hong Kong, apparently healthy, and involved in a range of physical activities. In an attempt to maintain euhydration, subjects were asked not to perform exercise, consume food or drink within two hours prior to visiting the laboratory, and to void the bladder prior to the assessment. Measurements were typically scheduled to begin at either 1430 or 1630 hours, with all measures, including duplicates, completed within a single visit to the laboratory. All measurements were taken by the same investigator who was a Level III accredited anthropometrist (International Society for the Advancement of Kinanthropometry: ISAK), and whose measurement precision and reliability had been re-assessed within the previous 3 months by an ISAK Criterion (Level IV) anthropometrist. The study ensured all subjects gave informed consent before participation, which provided anonymity, and was approved by the Institute's Research Ethics Committee.

The reference method in this study was the calculation of percentage body fat taken from the mean/medium of repeated anthropometric measures. Recent studies investigating multiple estimates of body fat percentage have shown that anthropometric methods incorporating skinfolds produce low levels of bias when compared to their reference 3- or 4-component models and have acceptable limits of agreement when compared to other methods.[6, 7, 18]

Reference method: measurement of percentage body fat (%BF) by the anthropometric method using ISAK procedures

Mass was measured to 0.05kg with the subject wearing minimal clothing using load-cell scales (UC-300, A&D Ltd, Japan). Skinfolds were measured using Harpenden skinfold calipers (John Bull, British Indicators Ltd, United Kingdom), whilst all lengths/breadths/girths/heights where taken using specialized anthropometric equipment (Centurion kit, Rosscraft, Canada). Body mass index (BMI) was calculated from mass / (height^2).

The calculation of %BF followed recommended guidelines[19] that utilized highly standardized ISAK anthropometric procedures requiring, in addition to height and mass, the precise measurement of 9 skinfolds, 13 girths, 8 lengths and 8 breadths. The description of these precise anthropometric measurements are detailed elsewhere.[20-22] Every measurement was taken in duplicate by the same Level III anthropometrist, with the mean value used for analysis, except if two skinfold measures varied by more than 5%, or if any length/breadth/girth/height varied by more than 1%, in which case a third measure was taken and the median value used for analysis. Since the anthropometric method requires extremely precise measurements,[23] the inter- and intra-tester reliability of the anthropometrist was assessed ahead of the study reported here. High inter-tester reliability was shown by the Level III anthropometrist producing a technical error of measurement (TEM) across 10 random anthropometric measures taken on each of 3 different subjects that were acceptably below the limits of 10% for skinfolds and 2% for all lengths/breadths/girths/heights when compared to a Level IV Criterion ISAK anthropometrist.[21] High intra-tester reliability was shown when the Level III anthropometrist produced TEMs for repeated measurements below 1% for all lengths/breadths/girths and below 3% for all skinfolds recorded in this study; in addition, the intraclass correlation coefficients (ICC) for each repeat measurement were consistently greater than 0.992.

Each subject's data were entered into the LifeSize (v.1) software analysis program.[24] The %BF for each subject was estimated using a 2-compartment model (Fat Mass and Fat-Free Mass) from the body density predicted from 14 (female) or 7 (male) regression equations that require different combinations of independent anthropometric variables,[21] yet whose measurement sites are consistent with the ISAK guidelines.[20, 22] Body density was transformed into %BF using the Siri-equation[25] and presented as a mean (±SD) value.

Experimental method: measurement of percentage body fat by bioelectric impedance

Duplicate measurements of bioelectrical impedance were made on all subjects with three foot-to-foot devices (UM-022; BF-350; TBF-410, Tanita Corporation, Japan), using a counterbalanced Latin-Square design to control for order-effects. As two devices (BF-350; TBF-410), permitted software selection to designate the subject to be 'athletic' or 'standard', all subjects were tested in duplicate using both settings. Subjects were later asked to detail their physical activity history to assess whether they meet the 'athletic' criteria. As the guidelines in the Tanita instruction manual for meeting the 'athletic' criteria were imprecise (>16 yr of age and 'exercise' >10hr/wk for >6months [no intensity indicated]; or having a resting heart rate of 'approximately 60 beats/min or less'; or have been fit for 'a number of years' but currently exercise <10hr/wk), the following precise criteria were used to establish an 'athletic' subject: they performed moderate-vigorous exercise >10hr/wk for >6months; or >5hr/wk for >5yr; or >4hr/wk for >10yr.

Only the TBF-410 allowed for an estimated correction of clothing mass during each measurement. Values of 0.1kg for a swim-costume; 0.3kg for basketball-style shorts; and 0.5kg for a t-shirt and shorts together were used. Values are reported for all subjects measured using the 'standard' setting (i.e., with no correction for athletic status), as well as 'corrected' for athletic status (i.e., where non-athletes were measured using the 'standard' setting, and athletes using the 'athletic' setting).

The predicted %BF was automatically produced by the Tanita manufacturer's proprietary software, which was set by the local Hong Kong representatives to give values based on their 'Asian regression equations', which the representatives considered applicable to the male and female Chinese subjects used in this study, although some evidence contrasts this.[26] A duplicate measure of body mass to 0.1kg was also recorded for each device.

Statistical analysis

Intra-measurement reliability was assessed in three ways: (i) an intraclass correlation coefficient (ICC) using a one-factor repeated measures ANOVA for each duplicate measure, or from the two closest measures if 3 measures were taken, (ii) the technical (or total) error of measurement expressed as a percentage of the mean score,[27, 28] and (iii) the coefficient of variation (sometimes called the within-subjects standard deviation or typical error) expressed as a percentage of the mean score (%CV).[29] Validity assessment was also performed in three ways: (i) by the technical error of measurement expressed as a percentage of the mean score (%TEM);[28] (ii) by using a least-squares linear regression and by examining whether the slope approximated to 1.0 and if the intercept approximated to zero. The random error of the BIA measurement was assessed by the standard error of the estimate of the regression line (SEE);[30] (iii) using the Bland-Altman method reported by Wong *et al*.[31] by plotting the differences between the two methods against their averages. A linear regression analysis was then used to examine the association between the differences and the aver ages. When the slope of the regression was not significant (p <0.05), the bias (mean error) and the 95% limits of agreement (LOA: 1.96 times the SD of the between-method differences) relative to the reference method were reported. Plots of the 'residuals versus predicted dependent values' were examined to see if the errors were similar for all subjects and checked for heteroscedasticity.[30]

Pearson correlations were used to examine the association between BMI and the mean %BF values determined from each measure, and paired t-tests with the Bonferroni adjustment used to examine if differences existed between each of the mean values of %BF as well as the mean mass recorded from each of the three BIA devices. Statistical analyses were performed using SPSS 11.0 and StatView 5.0.

Results

The mean anthropometic data for all subjects are shown in Table 1, with the percentage body fat (%BF) shown under standard conditions, and corrected for athletic status (5 males and 2 females met the criteria to be classified as being 'athletic'). All of the measures were highly reliable, with the lowest ICC value being 0.999; whilst reliability values shown by the %TEM and %CV were consistently below 1% for both %BF and the sum of 9 skinfolds (Σ9SF), and below 0.1% for all measures of body mass (Table 2). The validity analyses (Table 3) reveal considerably higher %TEM values when compared to the ISAK reference (range: 14.0 to 17.5%). The regression analysis revealed slopes that were close to 1.0

Table 1. Anthropometric mean (SD) data for all subjects, including the Body Mass Index (BMI), the percentage body fat (%) from each measurement device and the sum of 9 skinfolds

	Age (yr)	Mass (kg)	Height (m)	BMI (kg/m^2)	ISAK (%)	Σ9SF (mm)	UM022 (%)	BF350 (%)	TBF410 (%)	Corr350 (%)	Corr410 (%)
Total	22.2	58.9	1.68	20.7	18.1	107.9	21.4	20.7	20.2	18.4	17.9
(n=20)	(2.6)	(11.8)	(0.01)	(2.5)	(7.6)	(47.2)	(6.2)	(6.2)	(6.0)	(7.0)	(6.8)
Male	21.8	67.5	1.76	21.7	13.1	91.3	18.0	17.0	16.7	13.4	13.1
(n=10)	(2.4)	(10.0)	(0.01)	(2.1)	(5.7)	(44.5)	(4.2)	(3.6)	(3.5)	(3.5)	(3.4)
Female	22.7	50.3	1.60	19.7	23.1	124.5	24.8	24.3	23.7	23.3	22.8
(n=10)	(2.8)	(5.7)	(0.01)	(2.4)	(5.8)	(46.0)	(6.3)	(6.1)	(6.0)	(6.1)	(5.9)

ISAK = reference anthropometric method; Σ9SF = sum of 9 skinfolds; UM022 = standard Tanita UM-022; BF350 = standard Tanita BF-350; TBF410 = standard Tanita TBF-410; Corr350 = Tanita BF-350 corrected for athletic status; Corr410 = Tanita TBF-410 corrected for athletic status.

Table 2. Reliability results: analyses of body mass (mass) and the percentage body fat (%BF) from each device, plus the sum of 9 skinfolds (mm)

	A&D	ISAK	Σ9SF	UM022		BF350		TBF410		Corr350	Corr410
	mass	%BF	mm	mass	%BF	mass	%BF	mass	%BF	%BF	%BF
%TEM	0.03	0.78	0.95	0.07	0.83	0.04	0.45	0.05	0.48	0.47	0.48
%CV	0.04	0.80	0.83	0.06	0.92	0.04	0.40	0.05	0.47	0.44	0.48
ICC	1.000	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999

Data shown for the technical error of measurement expressed as a percentage of the mean score (%TEM), the coefficient of variation expressed as a percentage of the mean score (%CV) and the intraclass correlation coefficient (ICC). A&D = A&D UC300 scales; ISAK = reference anthropometric method; Σ9SF = sum of 9 skinfolds; UM022 = standard Tanita UM-022; BF350 = standard Tanita BF-350; TBF410 = standard Tanita TBF-410; Corr350 = Tanita BF-350 corrected for athletic status; Corr410 = Tanita TBF-410 corrected for athletic status.

(range: 0.95 to 1.17), with intercepts in the range of +0.55 to -5.42, and SEE values in a narrow range of 3.2 to 3.8. The Bland-Altman analysis produced a range of bias from +0.15 to -3.32 and 95% LOA also within a narrow range of 6.30 to 7.28. Only two of the five Bland-Altman comparisons produced regression slopes with a significant slope (Standard BF-350 and Standard TBF-410), suggesting that care is needed when interpreting these bias and LOA values.

With the exception of BMI, all of the measured variables were very significantly correlated (p<0.01) to each other, with r-values that ranged from 0.75 to 1.00 (Table 4). Σ9SF was only variable that was significantly correlated with BMI (r=0.63, p< 0.01), although the 'standard values' of %BF from each of the three bioelectric impedance devices nearly reached statistical significance (p=0.06 in all cases).

The paired t-tests with Bonferroni adjustment revealed small, yet significant, differences between the means of body mass determined by the UM-022 (+0.22 kg, p<0.01) and BF-350 (+0.05kg, p<0.01) when compared to the reference A&D UC300, but no significant difference for the TBF-410 (p=0.25). However, all three devices significantly overestimated the combined %BF using the standard measurement setting (no correction for athletic status) when compared to the reference ISAK measure: UM-022 (+3.2%, p<0.01), BF-350 (+2.6%, p<0.01), and TBF-410 (+2.1%, p<0.01), which was primarily due to each device significantly underestimating the male, but not the female, %BF. When the combined %BF was corrected for athletic status, neither the BF-350 (+0.3%, p=0.72), nor the TBF-410 (-0.2%, p=0.86) produced a %BF that differed significantly from the reference ISAK method, and similarly, no significant gender bias was detected.

Discussion

Limitations

The Hong Kong Chinese subjects who volunteered for this study were healthy university students enrolled in a Sports Science and Leisure Management degree. None of the relatively small number of volunteers exceeded the

Table 3. Validity results: analyses of the percentage body fat estimates from each of the 3 devices compared to the reference ISAK anthropometric model

Method compared to reference	%TEM	Regression Analysis			Bland-Altman Analysis				
		Slope	Intercept	SEE	R^2	Slope	p	Bias	LOA
Standard UM-022	17.5	1.07	-4.85	3.74	0.15	0.21	0.093	-3.32	7.19
Standard BF-350	14.8	1.13	-5.20	3.20	0.21	0.22	0.041	(-2.58)	(6.30)
Standard TBF-410	14.1	1.17	-5.42	3.20	0.27	0.25	0.020	(-2.10)	(6.39)
Corrected BF-350	14.1	0.95	0.68	3.80	0.03	0.09	0.446	-0.30	7.28
Corrected TBF-410	14.0	0.98	0.55	3.75	0.05	0.15	0.415	0.15	7.17

Data shown for the technical error of measurement expressed as a percentage of the mean score (%TEM); the slope, intercept and standard error of estimate (SEE) from a linear regression; the Bland-Altman analysis shows the bias plus 95% limits of agreement (LOA), and from the fitted regression line, its coefficient of determination (R^2) and whether its slope was significantly different to zero (p). Bracketed values show significant slope in the Bland-Altman plots, thus care must be used in interpreting both the Bias and LOA. Standard = normal body fat measure; Corrected = body fat adjusted according to athletic status.

Table 4. Pearson correlation matrix for Body Mass Index (BMI), the percentage body fat (%) from each device, plus the ISAK reference method and the sum of 9 skinfolds

	BMI	ISAK	Σ9SF	UM022	BF350	TBF410	Corr350	Corr410
BMI		M:0.97* F:0.91*	M:0.96* F:0.88*	M:0.74* F:0.97*	M:0.90* F:0.97*	M:0.89* F:0.97*	M:0.48 F:0.95*	M:0.48 F:0.95*
ISAK	0.34 (0.14)		M:1.00* F:0.99*	M:0.74* F:0.90*	M:0.86* F:0.90*	M:0.86* F:0.90*	M:0.49 F:0.94*	M:0.50 F:0.95*
Σ9SF	0.63* (<0.01)	0.93* (<0.01)		M:0.75* F:0.88*	M:0.86* F:0.88*	M:0.86* F:0.88*	M:0.49 F:0.94*	M:0.49 F:0.95*
UM022	0.43 (0.06)	0.88* (<0.01)	0.83* (<0.01)		M:0.93* F:1.00*	M:0.94* F:1.00*	M:0.47 F:0.92*	M:0.48 F:0.93*
BF350	0.42 (0.06)	0.91* (<0.01)	0.85* (<0.01)	0.98* (<0.01)		M:1.00* F:1.00*	M:0.43 F:0.93*	M:0.43 F:0.93*
TBF410	0.42 (0.06)	0.91* (<0.01)	0.85* (<0.01)	0.99* (<0.01)	1.00* (<0.01)		M:0.40 F:0.92*	M:0.41 F:0.93*
Corr350	0.19 (0.43)	0.87* (<0.01)	0.75* (<0.01)	0.86* (<0.01)	0.88* (<0.01)	0.87* (<0.01)		M:1.00* F:1.00*
Corr410	0.19 (0.43)	0.88* (<0.01)	0.75* (<0.01)	0.86* (<0.01)	0.88* (<0.01)	0.87* (<0.01)	1.00* (<0.01)	

Unshaded correlations [r and (p-value; * < 0.05)] shown for the combined group; shaded correlations shown for Males (M) and Females (F) separately. ISAK = reference anthropometric method; Σ9SF = sum of 9 skinfolds; UM022 = standard Tanita UM-022; BF350 = standard Tanita BF-350; TBF410 = standard Tanita TBF-410; Corr350 = Tanita BF-350 corrected for athletic status; Corr410 = Tanita TBF-410 corrected for athletic status.

recent Asian BMI guidelines[32] for obesity (27.5 kg/m^2), whilst only 15% (1 female, 2 males) exceeded the cut-point for overweight (23.0 kg/m^2). Although most participated in some regular sport, only 35% were classified as athletic according to the criteria stated in the Methods, and they cannot be considered to be a representative sample of their age group or the wider Chinese population. A further limitation is that bioelectric impedance is sensitive to the hydration status of the individual,[16] yet no direct measure of hydration status, independent of BIA, was made. This limitation was partially mitigated by reasonable attempts to ensure all individuals were at their normal state of euhydration prior to measurements being taken. Often DEXA, or ideally a 3- or 4-compartment chemical model, would have been used as a criterion standard for the measurement of %BF, however, resources were not available for such determinations, yet comparisons with 2-compartment reference models have been recently reported.[15] Furthermore, the use of the mean %BF measurement from multiple anthropometric equations (LifeSize v.1) helped reduce the potential systematic error caused by using a single predictive equation, and multiple anthropometric equations have been shown to have good agreement with %BF values from DEXA over a wide range of ages.[33] But as the aim of this study was to determine whether the BIA devices provided reliable and valid data that permitted them to be used instead of traditional anthropometric measures, it was therefore sufficient only to compare them with the ISAK method. Providing a comparison with a well-accepted criterion device for the measurement of body fat, such as DEXA, would clearly have been a bonus, yet this was not essential to fulfil the aims of this study.

Reliability

The within-day intra-device reliabilities for all measures of mass, Σ9SF and %BF were consistently very high, with the lowest ICC value being 0.999, whilst the %TEM and %CV values never exceeded 0.1% for mass or 1% for %BF. These results appear to be as good and often superior to other measures of within-day reliability for BIA systems,[5, 13, 17, 23, 34-36] supporting the hypothesis that all of these devices, including the basic BIA model, were extremely reliable. In fact, the %CV of all three Tanita devices used in this study were even below those of 0.17 (mass) and 1.73 (%BF) calculated from the repeatability data on Hong Kong children[37] from an earlier Tanita TBF-401 model. The very small variation in the ICC values in comparison to the greater variation shown in the %TEM and %CV values suggests that the %TEM and %CV may have greater discriminating power when duplicated measures show such small intra-device variations. As was hypothesized, the added measurement error introduced by the anthropometrist resulted in the highest %TEM and %CV values being found for the reference ISAK %BF (0.78% and 0.80% respectively) and Σ9SF (0.95% and 0.83% respectively). Yet all of these measurement errors are well below the recommended 2% limit,[38] and show that highly reliable measurements of body fat and sum of skinfolds can be made by experienced anthropometrists using highly standardized measrement procedures.[20]

Validity

Each of the three BIA devices showed marginal validity for %BF compared to the reference ISAK anthropometric model using the Bland-Altman analysis. When used under the standard mode the bias ranged from -2.10 to -3.32%, whilst the LOA remained no higher than approximately 7%. When two devices were corrected for athletic status, the bias was reduced to only -0.30 to 0.15%, with the LOA remaining around 7%. These bias and LOA findings for the Tanita models in this study (compared to a 2-compartment reference) are slightly lower than those noted in recent studies[6, 18] for other Tanita BIA models when compared to 3- and 4-compartment models. The SEE values from Table 3 ranging from 3.20 to 3.80% are similar to those reported from other recent BIA devices,[5, 35] whilst the TEM% values around 14% are similar to the value of 12% found by Moore *et al*.[34] when comparing skinfolds against BIA measures. These results show that the BIA devices used in this study have validity measures that are equal or slightly better than previous studies and that when compared to the ISAK reference, the BIA devices that allow correction for athletic status, are acceptably valid measures of %BF. That the validity of the estimated %BF improved when corrections were made for athletic status supports the findings of Swartz *et al*.[17] that the choice of mode (standard vs. athletic) is important when using such devices. Even though the very small amount of bias seen in body mass reported by two of the BIA devices were shown to be statistically significant, this amount of bias is considered to be relatively unimportant as it was typically <0.4%. Consequently, all three BIA devices were considered acceptably valid measures of body mass.

Correlation analysis

The finding that, for the combined group, all the correlations between the reference ISAK values and the estimators of body fat were significant and exceeded 0.87 (Table 4), indicates a high degree of association between these combined measures. Similar levels of association have been reported between BIA and other reference methods.[13, 14, 34] The only exception was that of BMI, which had a non-significant correlation of 0.34 with ISAK %BF, but significantly improved when the analysis was split by gender and likely reflected that, for the same BMI, females typically have a higher %BF than males. Several other BIA correlations showed significant changes when split by gender and may be due to how BIA is effected by the different android and gynoid body fat patterns between genders.[39] However, unlike previous studies,[36, 40] the foot-to-foot BIA devices in this study neither overestimated (females) nor overestimated (males) the %BF when corrected for athletic status, although in their standard mode all three BIA devices significantly underestimated the males values. These results may partially reflect improvements in the pre-programmed predictive equations supplied by the manufacturers, but again stresses the importance of the correct mode selection.

Summary

All three BIA devices were reliable in the measurement of mass and %BF. They were also acceptably valid in the measurement of body mass, as any detectable bias was considered to be of minor anthropometric importance. When using the standard mode to assess %BF, the male values were significantly underestimated by about 4%, but when corrected for athletic status, no significant differences in %BF were seen. All devices appeared to satisfactorily predict %BF in young Chinese females. Overall, only the BF-350 and TMF-410 were considered sufficiently valid that they can be used instead of more traditional anthropometric measurements. These two devices are therefore recommended for the determination of mass and body fat on young Chinese adults using the pre-set Asian predictive equations, as both models could be adjusted for athletic status. The greater portability of the BF-350 would favour its use in large field studies, or perhaps other lightweight models that can also account for athletic status. However, further cross-validations with 3- and 4-compartmental models are needed to refine the validity of these bioelectric impedance devices and should involve a much wider range of participants.

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Original Article

Can bioelectric impedance monitors be used to accurately estimate body fat in Chinese adults?

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生物電阻監測器能否準確評估成年華人的體脂肪?

現有很多以實驗室為本的測量體脂肪方法存在，但當中很少能迅速及容易地被應用到田野研究。生物電阻分析法(BIA) 己被發展成一個攜帶式腳-到-腳的系統，可以在田野研究時評估體脂肪，但是不清楚 BIA 的數據是否可以比得上傳統用於大型流行病學的體位測量法。本研究重複兩次測量二十名年輕華人體脂百分比(%BF)，以分析三種不同 BIA 儀器(低、中及高價位)的信度及效度。與衍生自三十八個重複兩次的體位測量值及最少七條迴歸方程式的平均數得到的% BF 為參考值作比較 。三種 BIA 儀器都是可靠的(信度)，組內相關係數從未低於 0.999，測量技術誤差及變異係數(以百分比表示)均低於 1%。效度分析揭露出三種 BIA 儀器，在使用標準的測量設定(即未修正運動狀態)的情況下，與參考方法比較% BF 會被顯著的高估：UM-022 (+3.2%, *p*< 0.01), BF-350 (+2.6%, *p*< 0.01), 和 TBF-410 (+2.1%, *p*< 0.01)。而運動狀態修正後的%BF 為，不論 BF-350 (+0.3%, *p* = 0.72)或 TBF-410 (-0.2%, *p*= 0.86)所計算出來的%BF 均與參考方法所得的結果沒有明顯差異。總括而言，在修正運動狀態後，這三種 BIA 儀器都是可靠的，可以被推薦為在這個族群的樣本中測量身體質量及% BF 的有效的田野測量方法。

關鍵字：效度、信度、體組成、生物電阻分析法。