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To Predict Body Composition of Children and Adolescents by BIA in China

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ABSTRACT

Objective : The paper aims to provide predictive coefficients via BIA for the assessment of body composition in children and adolescents to serve clinical as well as research purposes. **Methods** : Body composition via dual-energy x-ray absorptiometry (DXA) and bioelectric impedance as well as other anthropometric index were derived from meaurements on 1026 children and adolescents aged from 6 to 18 years from Beijing City. The best subset regression and principle component analysis were adopted to build the predictive coefficients with the logarithm of body composition via DXA as response variable. **Results** : Condition index φ of fat-free mass multiple linear regression achieves 113.49 and 91.18 for males and females respectively, demonstrating severe multicollinearity among anthropometric indexes in children and adolescents. BIA predictive coefficients base on the best subset regression and principle component analysis boast a content predictive value for lean mass ($r^2 = 0.9697$ and 0.9664 for boys and girls respectively, $p < 0.0001$) and for Fat% ($r^2 = 0.7705$ and 0.6959 for boys and girls respectively, $p < 0.0001$). **Conclusions** : BIA method is applicable for the prediction of body composition for children and adolescents. (*J Community Nutrition* 6(3) : 121~124, 2004)

KEY WORDS : BIA · body composition · DXA · children · adolescent.

Introduction

Body composition analysis play an important role in evaluating growth and development as well as nutrition status of children and adolescents. Many different techniques, such as hydrodensitometry, isotope dilution, total body potassium and so on can be used to determine fat-free mass (FFM) and fat mass, but they are not easily applicable. Bioelectric impedance analysis (BIA) is a rapid, easy, noninvasive, safe, and economical method for body composition analysis (Lukaski 1985). Although BIA measurements have been validated in healthy adults (Lukaski et al. 1986 ; Segal et al. 1988 ; Deurenberg et al. 1980), it is not fully documented whether it can predict FFM and fat mass equally well in children and adolescents for the reasons of their tremendous developmental variations in body composition. Traditionally, underwater weighting method is usually used as a reference one to establish BIA predictive coefficients, but the method intends to under-estimate fat percentage of children and adolescents systemically (Lohman 1986). Thus, BIA predictive formula based on an appropriate method determining body composition is important both in theory and in practice.

Subjects and Methods

1. Subjects

1026 children and adolescents (457 males and 569 females respectively), aged from 6 to 18 years from Beijing, China were included in this study and informed consents endorsed by the subjects' parents. All subjects were free from chronic diseases and abnormalities. Their age composition is provided in Table 1.

2. Methods

All subjects were scanned by NORLAND XR-36 dual-energy x-ray absorptiometry (DEXA) calibrated every day using a calibration standard supplied by the company. The in vivo coefficient of variation of the scan ranged from 0.56 to

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0.65 percent. A four-polar bioelectric impedance analyzer was used as an apparatus measuring subjects' bioelectric impedance and reactance. Male subjects dressed in shorts, females dressed in shorts and cotton T-shirts. Height and seating height were measured to the nearest millimeter using a standard stadiometer. All subjects were weighted to the nearest 0.1kg on a RGT-140 lever scale. The girth of chest, waist, hip, tight upper-arm, relaxed upper-arm and calf were measured to the nearest millimeter by flexible meters, Upper-limb and calf limb by Martin meter. Foot lengths were measured to the nearest millimeter using a specially designed foot length meter. Simultaneously, birthdays as well as the day at visit were fully documented to calculate the subjects' denary age.

Some derived indexes were calculated as follows :

Waist hip ratio = waist girth/hip girth

BMI = weight (kg) /height^2 (m) ;

Arm girth difference = upper-arm tight girth - upper-arm relax difference ;

BIA index = height^2/bioelectrical impedance.

3. Statistics

All statistical analyses were performed with software SAS 8.2 edit. The best subset regression and principle component analyse were adopted to build the predictive coefficients with the logarithm of body composition via DEXA as response variable. All variables introduced into the regression, see Table 2.

Results

Table 3 shows BIA predictive coefficients of fat free mass for both male and female, which was established with the logarithm of body composition via DEXA as response variable, and with all variables listed in Table 2 as independent

Table 1. Age composition of the subjects

Age group	Male	Female
6 –	8	5
7 –	19	34
8 –	18	28
9 –	28	34
10 –	43	53
11 –	70	82
12 –	74	66
13 –	54	73
14 –	50	58
15 –	35	46
16 –	24	41
17 –	15	28
18 –	19	21
Total	457	569

Table 2. List of variables introduced into regression equations

Variables	Unit
Weight	kg
Age	year
Height	cm
BMI	kg/m^2
BIA index	m^2/Ω
Chest girth	cm
Waist circumference	cm
Hip girth	cm
Waist hip ratio	
Mid-upper arm tight circumference	mm
Mid-upper arm loose circumference	mm
Arm girth difference	mm
Calf girth	cm
Seating height	cm
Uper limb length	cm
Calf length	cm
Foot length	cm

Table 3. *FFM regression results based on C (p) selection method*

	Number in model	C (p)	R-Square	Adjusted R-Square	Variables in model
Male					
	5	29.7991	0.9718	0.9715	Age, height, BIA index, foot length, BMI
	5	32.9570	0.9716	0.9712	Age, height, BIA index, mid-upper arm tight circumference, BMI
	5	40.0396	0.9711	0.9708	Weight, age, height, BIA index, BMI
Female					
	5	19.5542	0.9535	0.9530	Height, BIA, index, seating height, foot length, BMI
	5	20.7078	0.9534	0.9529	Weight, height, BIA index, mid-upper arm loose circumference, BMI
	5	22.5927	0.9532	0.9528	Age, height, BIA index, foot length, BMI

Table 4. FFM multiple linear regression collinearity diagnostics

	N	Eigenvalue	Condition index	Proportion of variation					
				Intercept	Age	Height	BIA index	Foot length	BMI
Male	1	5.90123	1	0.00006158	0.00025686	0.00001779	0.00028076	0.00004285	0.00058247
	2	0.06244	9.72172	0.01046	0.00809	0.00025791	0.09137	0.00136	0.00032581
	3	0.02731	14.69938	0.00065706	0.07018	0.00081777	0.00033868	0.00103	0.5496
	4	0.00692	29.2111	0.01186	0.72525	0.00283	0.32677	0.01113	0.31063
	5	0.00164	59.97206	0.52734	0.01761	0.00188	0.21373	0.51194	0.02566
	6	0.00045818	113.48829	0.44962	0.17862	0.9942	0.36751	0.47449	0.1132
Female	1	5.89845	1	0.0000989	0.00040917	0.00002878	0.00104	0.00004745	0.00071262
	2	0.05273	10.57622	0.01479	0.00405	0.00095559	0.43478	0.0029	0.00589
	3	0.02482	15.41529	0.01165	0.43183	0.00004194	0.22656	0.00195	0.00026489
	4	0.02129	16.6444	0.00163	0.0293	0.00156	0.12694	0.00176	0.97253
	5	0.00199	54.39146	0.8696	0.13867	0.03373	0.13809	0.3418	0.00709
	6	0.00070953	91.17657	0.10224	0.39574	0.96368	0.07257	0.65154	0.01351

Table 5. Eigenvalues of the correlation matrix of FFM principle component analysis

	N	Eigenvalue	Difference	Proportion	Cumulative
Male	z1	3.96061959	3.28182124	0.7921	0.7921
	z2	0.67879836	0.46235954	0.1358	0.9279
	z3	0.21643882	0.10980047	0.0433	0.9712
	z4	0.10663835	0.06913347	0.0213	0.9925
	z5	0.03750488		0.0075	1.0000
Female	z1	3.81470125	3.20030082	0.7629	0.7629
	z2	0.61440042	0.23090502	0.1229	0.8858
	z3	0.3834954	0.24265440	0.0767	0.9625
	z4	0.14084101	0.09427909	0.0282	0.9907
	z5	0.04656192		0.0093	1.0000

variables. Five variables were included in the formula with regards of practicability, convenience and regression effect with CP statistics as the best regression role.

Table 4 reveals that condition index φ of FFM multiple linear regression achieves 113.49 and 91.18 for male and female respectively, demonstrating severe multicollinearity among variables.

Cumulative proportion of the first eigenvalue z1 and second one z2 of the correlation matrix for FFM principle component analysis amount to 0.9279 and 0.8858 respectively, comprising 92.79% and 88.58% information of the original five variables (see Table 5).

Predictive coefficients calculated based on z1 and z2 are shown in Table 6. BIA index contributes most to the predictive equations for the male and BMI least (standardized para-coefficient 0.2388 and 0.1892 respectively), and height, age and foot length distributed between them in turn ; BIA

Table 6. Fat free mass predictive coefficients

Male			Female		
Variables	b	β	Variables	b	β
Intercept	7.7546		Intercept	7.6717	
Age	0.0291	0.2152	Age	0.0228	0.2144
Height	0.0054	0.2334	Height	0.0053	0.2271
BIA index	0.0064	0.2388	BIA index	0.009	0.2481
Foot length	0.038	0.2149	Foot length	0.0397	0.1988
BMI	0.0162	0.1892	BMI	0.0174	0.2306

Table 7. BIA fat-free mass and fat percentage predictive coefficients effect test

	Logarithm of fat-free mass			Fat percentage		
	R-Square	RMSE	Pr>F	R-Square	RMSE	Pr>F
Male	0.9697	0.0641	<0.0001	0.7705	4.7563	<0.0001
Female	0.9664	0.0556	<0.0001	0.6959	3.8142	<0.0001

index contributed most to the formula for the female and foot length least (standardized partial regression coefficient 0.2481 and 0.1988 respectively), and BMI, height and age distributed between them side by side.

Table 7 shows that the decision coefficients of the predictive formula for fat free mass achieve 0.9697 and 0.9664 for the male and female respectively, $P < 0.0001$) and ones for fat percentage achieve 0.7705 and 0.6959 respectively ($P < 0.0001$).

Discussion

The research adopted the best subset regression or all possible subsets regression instead of step regression method to establish predictive equations, for step regression method can only promise that all variables inside 'the best regression' remain significant and all variables outside don't, as can't promise the best adjusted R^2 or the least residual standard error of the equations. The more appropriate way was to list all possible regression equations and select the best one according to some role. With the CP statistics as the role can compare all coefficients with different number of variables and thus get the best one (Zhang 2002).

Conveniency of measuring of anthropometric indexes and application of predictive equations should be also taken into account. The predictive equations including age, height, BIA Index, foot length and BMI appeared for both male and female, and they all have similar adjusted R^2 with others respectively. It is reasonable to select these indices for establishing predictive equations.

Anthropometric indices of children and adolescents are characterized by intense multicollinearity. Existence of multicollinearity influences estimate of regression coefficients and precision of predicted values. In this study, Condition index φ of FFM multiple linear regression were much more than 10 according to collinearity diagnostics, proving the opinion. Principle component analysis is an effective way to avoid multicollinearity among variables in medical practice (He, Su 2002 ; Gao 1997). The research analysis also combined the method to improve predictive precision.

What differs from other body component predictive coefficients is that there exists an important variable - foot length, in the formula provided by this paper. Possible reasons maybe that foot length has effects on bioelectrical impedance measuring, or foot length carries some information of body composition of children and adolescents itself, since it intends to begin to develop in an accelerated way before other parts of the body, and the acceleration intends to end similarly.

Conclusion

Although many researchers validated effectiveness of BIA as a method measuring body component (Segal et al. 1985 ; Lukaski 1986 ; Jackson 1969), few researches have been carried out on children and adolescents. The research found that fat percentage of children and adolescents calculated on the formula provided by the company were significantly lower than DXA results, which were prepared for adults originally, and residual analysis chart revealed a significant trend simultaneously. BIA results show high decision coefficients with DXA, revealing that BIA method is also applicable for the prediction of body composition for children and adolescents.

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