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New Skinfold-thickness Equation for Predicting Percentage Body Fat in Chinese Obese Children

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Abstract

Objective: To validate existing skinfold thickness predicting equations and to develop an equation for estimating body fat composition in obese Chinese children. ***Design:*** Cross-sectional study. ***Subjects:*** One hundred and thirty-eight Chinese obese children, 37 girls and 101 boys with mean age and body mass index (BMI) of 11.9 years (SD 2.7) and 29.7 Kg/m^2 (SD 4.8) respectively, referred for medical assessment were recruited. ***Measurements and methods:*** All subjects underwent physical examination and anthropometric measurement. Total percentage of body fat (%FM) was measured by dual-energy X-ray absorptiometry (DEXA) scan (%FM-DEXA). Three skinfold-thickness predicting equations for estimating %FM (%FM-SF) were compared with the measured %FM-DEXA. ***Results:*** The mean male and female percentage body fat measured by DEXA were 36.6% (SD 6.8) and 39.0% (SD 4.2) respectively. There was significant gender difference in %FM-DEXA (p=0.05). The Durnin & Rahaman equation (%FM-DR-SF) best predicted %FM in girls with a mean difference of %FM-DEXA-DR-SF of 0.76% (SD 4.0) but overestimated %FM in boys with a mean difference of -1.01% (SD 5.7). Lohman equation was the best in estimating %FM in boys. The mean differences of %FM-DEXA-L-SF were -0.94% (SD 5.62) and -2.58% (SD 4.5) for boys and girls respectively. The gender difference as documented by DEXA was only demonstrated by the Lohman equation. Slaughter equation overestimated %FM in both genders. The mean differences %FM-DEXA-Sla-SF was -8.1% (SD 8.6%) in boys and -5.2% (SD 5.28%) in girls. A new predicting equation was derived for local use. ***Conclusion:*** Existing equations are inaccurate in estimating percentage of body fat in obese Chinese children. A specific equation based on skinfold thickness was derived for estimation of %FM in obese Chinese children.

Key words Body fat distribution; Children; DEXA; Obese; Skinfold-thickness

Introduction

Obesity is associated with a variety of metabolic disturbances and long-term cardiovascular complications. The global obesity epidemic has also affected the paediatric population,[1-4] including Hong Kong children.[2,5,6] Using the International Obesity Task Force cut-offs, 16.7% of Hong Kong children were overweight or obese in 2005/6, which was a 5.1% increase since 1993.[7]

Body fat composition is directly linked to obesity-related complications. Hence, different practical methods were developed to estimate body fat and fat free mass. Percentage body fat (%FM) can be estimated by numerous techniques including hydrodensitometry, bioelectrical impedance, isotope dilution and dual-energy X-ray absorptiometry (DEXA). These methods are however time consuming and are not easily accessible. In 1956, Siri was the first to derive an equation for estimating body fat.[8] This calculation was formulated based on the assumption that subcutaneous fat

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accurately reflected body fat content. Slaughter et al, subsequently derived an equation that involves simple linear regression without the need to measure body density. This equation is widely accepted and used in the paediatric population.[9] Various racial specific equations were then derived for population based studies.

However most of these equations were derived from adult Caucasians[10-15] or healthy children.[9,16] Their validity in predicting %FM in obese children has not been established.[17-19]

This study aimed to validate existing skinfold thickness prediction equations and to derive a new equation for estimating body fat percentage in obese Chinese children.

Methods

Consecutive children aged 7 to 18 years with primary obesity referred by their primary health care physicians for specialist medical assessment were recruited. The study was carried out during the period between 1 January 2000 and 31 December 2004. All recruited children had a body mass index (BMI) above the 95th percentile according to local sex- and age-specific reference range.[20] The study was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong and informed consent was obtained from the subjects and their parents prior to assessment. Each child underwent a complete physical examination including anthropometric measures. Weight (Wt) and standing height (Ht) were measured with a calibrated weighing scale and stadiometer respectively using standard methods.[21] The percentage of body fat was determined by the multiple skinfold (SF) technique performed by a single observer (DC) using a Holtain Skinfold Caliper (Holtain Ltd, Crosswell, United Kingdom). Skinfold-thickness was measured at the biceps, triceps, subscapular and suprailiac regions according to standard procedures.[22] Each skinfold was measured three times and reported as the average of the three measurements. Waist and hip girth measurements were obtained using an inelastic cloth measuring tape around the level of greatest girth of the abdomen and hip respectively.[23] Assessment of obesity included the four skinfold measurements and BMI (kg/m^2). Measurements of body central fat distribution included the waist to hip ratio (WHR) and conicity index (ConI) which is a function of waist circumference (WC), weight, and height.[24] [The formula for ConI is $\frac{WC}{0.109*\sqrt{Wt/Ht}}$. The upper body fat distribution was demonstrated by centrality index (CenI) which is calculated from subscapular to triceps skinfold ratio.

Fat free mass was measured by a total body scanner (QDR4500A. Hologic, Waltham, MA, USA) using array mode. This equipment used a switched pulse stable dual-energy X-ray operating at 100 and 140 kV. An automatic internal reference system with a calibration wheel achieved the fat free mass calculation. Fat free mass was equal to subtract FM from body weight (BW). Fat mass was equal to %FM times BW. Percentage of body fat was calculated accordingly.

Two models of existing prediction %FM-SF equations (Table 1), derived from different populations, were compared with measured %FM-DEXA.

Statistics

SPSS for Windows (14, SPSS, Inc., Chicago, IL) was used in the analysis, and the level of significance was set at

Table 1 Two models of existing skinfold-thickness equations to predict percentage body fat

Source	Equation
Density model	[4.95/(K1-K2 logS) - 4.5] x 100
Durnin & Rahaman (%FM-DR-SF)	[4.95/(1.1369-0.0598 x logS) - 4.5] x 100
Lohmann	[5.28/D-4.86] x 100
Linear regression model	
Slaughter (%FM-DEXA-Sla-SF)	Boys=0.783*(sum of triceps and subscapular skinfold) - 1.7
	Girls=0.546*(sum of triceps and subscapular skinfold) + 9.7

K1, K2 are population dependent constants

S is the sum of biceps and subscapular skinfold-thickness (mm)

D, boys [g/ml] = 1.1690-0.0788*(log(sum of four skinfolds: biceps, triceps, subscapular and suprailiac))

D, girls [g/ml] = 1.2063-0.0999*(log(sum of four skinfolds: biceps, triceps, subscapular and suprailiac))

5% for all comparisons.

The data were normally distributed and presented as mean values with standard deviations. Gender differences were determined using Independent *t*-test. For the comparison between DEXA and the skinfold-thickness equations, the percentage of body fat was examined by paired *t*-test with a positive difference indicating a relative underestimation of the percentage of body fat, and a negative difference suggesting a relative overestimation of percentage of body fat.

Linear regression analysis was used to derive the generalised equation. The dependent variable was percentage of body fat determined by DEXA. The independent variable was the sum of four skinfolds. The agreement of the equation was checked by examining the intraclass correlation

Results

A total of 138 children, 37 girls and 101 boys were recruited. None of the subjects had clinical evidence of underlying disease that could have caused secondary obesity. Their mean age was 11.9 years (SD 2.7) and the mean BMI was 29.7 kg/m^2 (SD 4.8) (Table 2). BMI (z-score) was significantly higher in girls; whilst WHR and conicity index were greater in boys.

The mean overall, male and female percentage body fat measured by DEXA was 37.3% (SD 6.3), 36.6% (SD 6.8) and 39.0% (SD 4.2) respectively. There were significant gender differences noted in %FM-DEXA (p=0.05) with girls having a higher degree of %FM (Table 3).

Calculated density model: The Durnin & Rahaman equation (%FM-DR-SF) best predicted %FM in girls with a mean difference of %FM-DEXA-DR-SF of 0.76 % (SD 4.0).[10] %FM-DR-SF overestimated %FM in boys with a mean difference of -1.01% (SD 5.7). Lohman equation was the only equation that significantly differentiated %FM-DEXA in both genders. %FM-DEXA-L-SF best predicted boys' %FM with mean differences of -0.94% (SD 5.62) and -2.58% (SD 4.5) for boys and girls respectively.[25]

For linear regression model, Slaughter equation (%FM-Sla-SF) overestimated %FM in both genders.[9,11,16] The mean differences of %FM-DEXA-Sla-SF was -8.09% (SD 8.6)

Table 2 Demographic and clinical characteristics of subjects

	Overall (138)		Boys (101)		Girls (37)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age	11.9	2.7	11.8	2.6	12.2	3.0
Weight (kg)	69.1	21.4	68.7	21.5	70.2	21.3
Height (cm)	150.8	14.5	150.8	15.0	150.8	13.3
Body mass index (BMI)	29.7	4.8	29.5	4.5	30.2	5.6
BMI z-Score	2.21	0.46	2.12***	0.43	2.46***	0.47
Waist	87.8	10.8	88.3	10.9	86.4	10.5
Hip	98.8	12.7	98.00	12.2	101.1	14.0
Waist to hip ratio	0.89	0.06	0.90***	0.06	0.86***	0.05
Biceps	19.4	6.3	19.5	6.7	19.0	5.0
Triceps	27.8	6.6	27.3	6.8	29.1	6.2
Subscapular	32.5	6.5	32.0	6.6	34.1	6.0
Suprailiac	33.0	6.3	33.0	6.7	33.0	5.3
Centrality index	1.20	0.24	1.20	0.23	1.20	0.26
Conicity index	1.21	0.06	1.22**	0.06	1.18**	0.05
% of BodyFat (DEXA)	37.3	6.3	36.6*	6.8	39.0*	4.2
Durnin & Rahaman	37.8	2.8	37.7	3.0	38.2	2.1
Slaughter	44.6	8.8	44.7	9.6	44.2	5.8
Lohmann	38.6	4.5	37.6***	4.3	41.5***	3.8

*p=0.05; **p=0.001; ***p<0.001

Table 3 Mean differences of %FM measured by DEXA and skinfold prediction equations

		Paired differences					
					95% CI of the difference		
		Mean	SD	SEM	Lower	Upper	*t*
Overall	%FM-DEXA-DR-SF	-0.54	5.29	0.45	-1.43	0.35	-1.20
	%FM-DEXA-Sla-SF	-7.35*	7.89	0.67	-8.65	-6.00	-10.91
	%FM-DEXA-L-SF	-1.38**	5.37	0.46	-2.29	-0.48	-3.02
	%FM-DEXA-Current	-0.001	5.23	0.45	-0.88	0.88	-0.003
Boys	%FM-DEXA-DR-SF	-1.01	5.65	0.56	-2.13	0.10	-1.81
	%FM-DEXA-Sla-SF	-8.09*	8.55	0.85	-9.78	-6.41	-9.52
	%FM-DEXA-L-SF	-0.94	5.62	0.56	-2.05	0.17	-1.69
	%FM-DEXA-Current	0.007	5.67	0.56	-1.11	1.12	0.012
Girls	%FM-DEXA-DR-SF	0.76	3.93	0.65	-0.55	2.07	1.18
	%FM-DEXA-Sla-SF	-5.23*	5.28	0.87	-7.00	-3.47	-6.03
	%FM-DEXA-L-SF	-2.58**	4.50	0.74	-4.08	-1.09	-3.50
	%FM-DEXA-Current	-0.023	3.85	0.63	-1.31	1.26	-0.037

*p<0.0001; **p<0.005; SD=Standard derivation; SEM=Standard error of mean; *t*=*t* value

in boys and -5.2% (SD 5.3) in girls.

As all skinfold variable were significantly associated with the percentage of body fat, four skinfolds: biceps, triceps, subscapular and suprailiac were summed to provide a composite variable S-SK, an estimate of body fat. A new equation for each gender was derived for our population of obese Chinese children.

Equation-1a (male) : %FM=19.088+0.157xS-SK
(R square=0.300)
Equation-1b (female) : %FM=28.725+0.089xS-SK
(R square=0.146)
(S-SK: sum of four skinfolds: biceps, triceps, subscapular and suprailiac)

These newly derived equations had reasonable intraclass correlation, the Cronbach's alpha of the prediction equation for boys and girls were 0.752 and 0.701 respectively. Deviation of the equation predicted fat percentage from DEXA measurements is shown in Figure 1. The plot of the error of fat estimate across age was scattered, ranging from -75% to 25%. The linear regression of %FM and skinfold thickness is shown in Figure 2, the R square for boys and girls were 0.3 and 0.146 respectively.

Discussion

In this study, we found existing skinfold prediction equations to be inaccurate in estimating %FM in our population of obese Chinese children. Based on the obtained data, a new prediction equation was derived for local use.

The major health problem of metabolic syndrome is directly related to the accumulation of body fat mass.[26] Accurate estimation of body fat composition with simple and easily accessible practical clinical methods will be important to help tackle the obesity epidemic in both adults and children. Skinfold-thickness prediction equations have been derived from various populations to provide a simple mean in assessing percentage body fat. The Lohman, Durnin & Wormersley (DW) and Durnin & Rahaman (DR) were similar equations derived using the same basic principle.[11] The Lohman equation[25] provided the closest estimation of %FM in male obese Chinese children even though it was shown to be inaccurate in estimating body fat composition when compared with bioelectrical impedance analysis (BIA) and DEXA in 610 German healthy children where it tended to over-estimate body fat composition at increased levels of %FM.[27] This over-estimation was also seen in our cohort of obese girls who had higher %FM.

The Durnin and Wormersley equation (%FM-DW-SF) was based on skinfold-thickness and body density measurements of 481 subjects aged between 16 and 72 years old.[16] This equation was assessed to be accurate in healthy, but not obese, adults.[28,29] The high proportion of adults recruited for deriving the equation may affect its' accuracy when applied to the paediatric age group. The Durnin & Rahaman equation was a modification of DW. An additional 45 young women, 86 adolescents boys and 38 adolescent girls were studied, allowing it to provide a more accurate

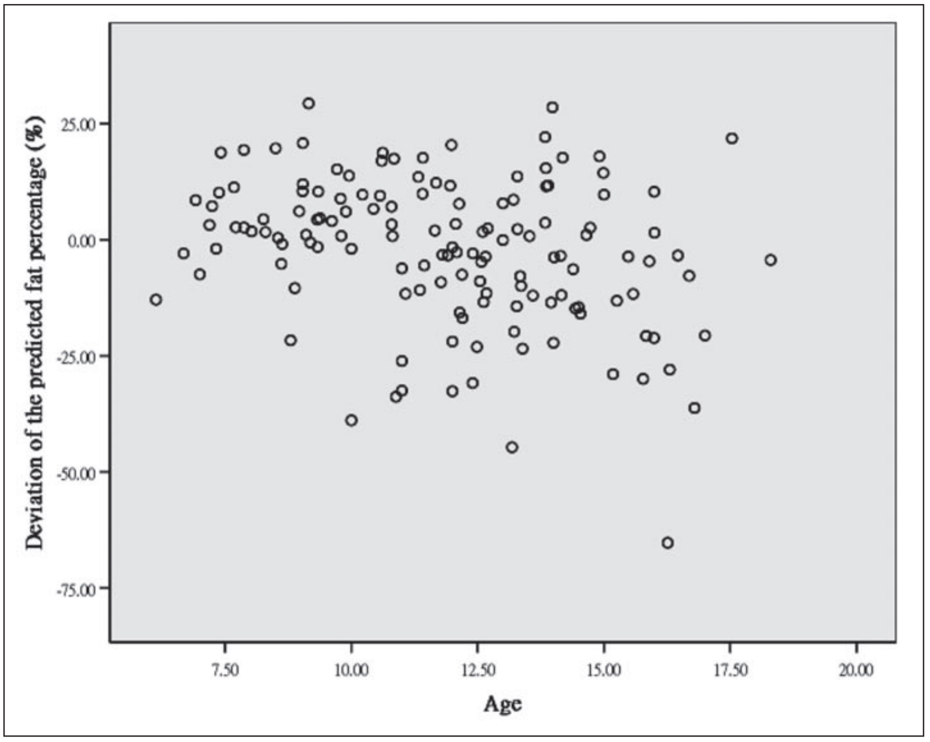

Figure 1 Deviation of the predicted fat percentage was calculated by the new equation minus the total percentage of body fat determined by DEXA.

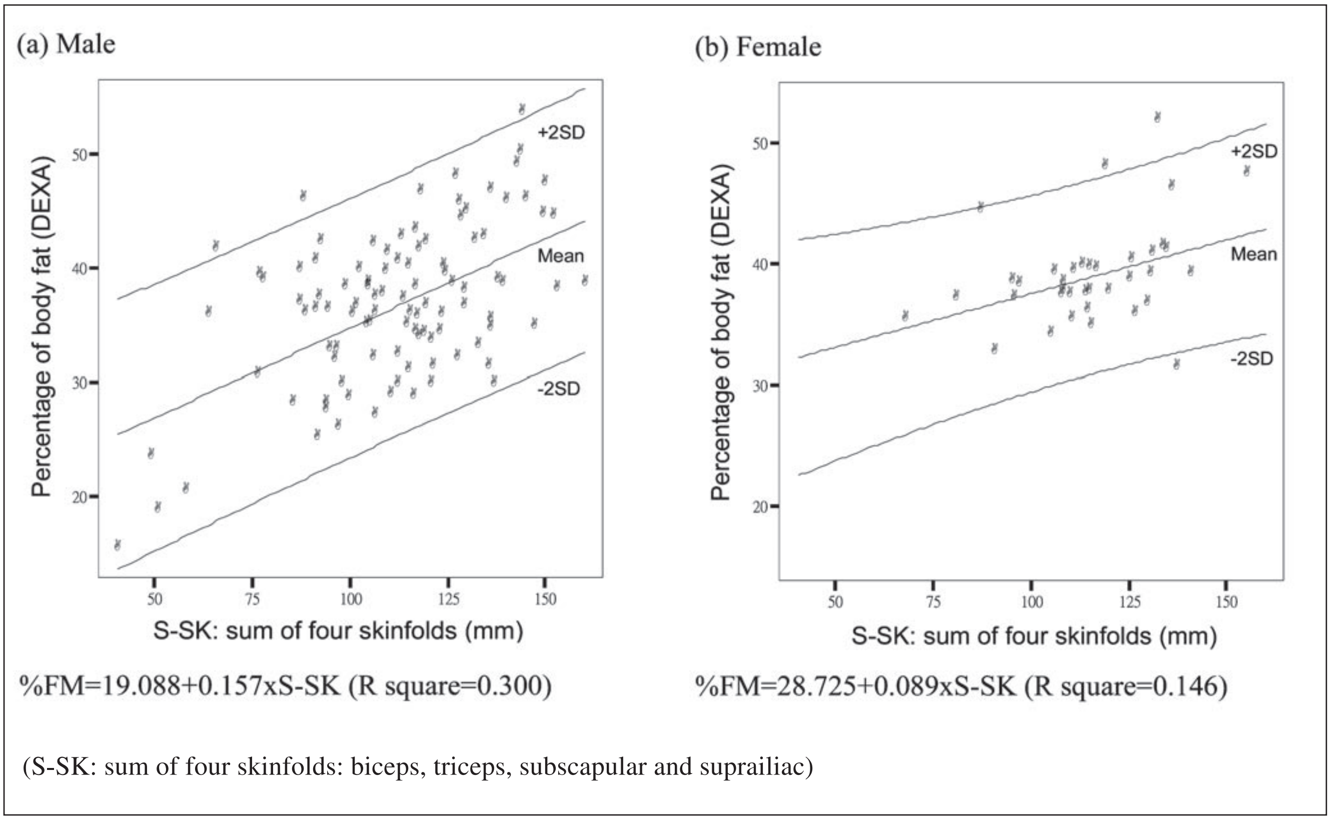

Figure 2 The linear regression of %FM and the skinfold thickness.

estimation of %FM in obese girls.[10] In fact, DR was the most accurate equation in predicting for %FM in our population of obese girls.

Slaughter equation over-estimated %FM of our obese children. Slaughter et al studied 310 subjects aged 8-29 years in a multi-compartmental model of body composition by combining measures of total body density, total body water and bone mineral density.[9] Applying this equation in different paediatric populations has yielded conflicting results. Janz et al found the equation to be promising in estimating body composition in 122 healthy children aged 8-11 years.[30] Wong et al recommended the use of Slaughter equation for female African Americans and white female adolescents as its accuracy and simplicity were demonstrated in 112 females aged 13 years.[31] Rowe et al however provided conflicting results when they studied more than 1200 children aged 7-14 years and found a significant difference between %FM estimated by BIA and %FM-Sla-SF.[17] These conflicting results could probably be explained by racial differences and the different study methods in measuring body fat composition.

There are certain limitations to our study. Firstly, we did not record pubertal staging of the subjects and hence, more detail explanations on the age dependent negative derivation cannot be drawn. Secondly, girls accounted for only a quarter of the study population. It will be important to confirm accuracy and validity of these newly derived equations prospectively in future studies. One advantage of our study involved the use of DEXA scan measurements as "gold standard" reference for %FM. DEXA readings have been shown to have significantly good correlations with other imaging-based methods of body composition assessment.[32]

Conclusion

In conclusion, existing equations could not accurately predict %FM in obese Children subjects. Based on the obtained data, we have derived a new skinfold equation for estimating %FM in Chinese children, Further studies will be needed to validate its accuracy.

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