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Development and Validation of a Simple Equation to Fat Mass and Percentage of Body Fat in Children and Adolescents

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Abstract
Background: This study aimed to develop and validate a simple equation to fat mass (FM) and percentage of body fat (PBF) in children and adolescents.
Methods: Participants consisted of 404 children and adolescents (176 males and 228 females, 5-18 years old) randomly divided into Derivation (n = 279) and Validation (n = 125) groups. FM and PBF were measured by a bioelectrical impedance analyzer. Based on demographic variables retrieved from the derivation group, 10 FM and 10 PBF predictive equations were developed using multiple regression. Finally, the most accurate model (using the coefficient of determination - R^2) was chosen and validated on the validation group.
Results: The best FM and PBF equations, which were derived from demographic characteristics, were: FM (kg) = Weight (kg) x 0.15 + BMI x 1.53 + Sex x 3.40 – Age (years) x 0.37 – 26.20; where sex = 1 for male and 0 for female. R = 0.97, R^2 = 0.94, standard error of the estimate (SEE) = 3.74 kg. PBF (kg) = 0.31 x Height (cm) - Weight (kg) x 0.59 + BMI x 2.98 + Sex x 6.17 – Age (years) x 0.76 – 52.84; where sex = 1 for male and 0 for female. R = 0.90, R^2 = 0.82, SEE = 4.88 kg.
Conclusion: Our predictive equations accurately predicted FM and PBF using simple parameters (height, weight, BMI, sex, and age) in children and adolescents.
Keywords: Percentage of body fat, Fat mass, Predictive, Equation, Children, Adolescents

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Introduction

Excess body weight has been known as an increasing health-related problem in children and adolescents during the past three decades all over the world, especially in developing countries (1,2). Furthermore, excess body weight in childhood and adolescence is associated with an increased risk of chronic disorders and diseases in adulthood, including obesity (3), ischemic heart disease, type 2 diabetes mellitus (1), hypertension (4), dyslipidemia (5), asthma (6), metabolic syndrome, liver disease, some types of cancers, and consequently, premature death (7).
The World Health Organization (WHO) defines obesity as abnormal or excessive fat accumulation that may impair health (8). Thus, by using accurate and reliable techniques in childhood, more effective prevention and treatment strategies for excess body fat detection can be achieved, which can reduce obesity risk in adulthood (9). Dual x-ray absorptiometry (DXA), air displacement plethysmography (ADP), hydrostatic weighing, and bioelectrical impedance analysis (BIA) are some available methods to assess the percentage of body fat (PBF) and body fat mass (FM) (10). Various studies have shown that BIA correlates well with PBF and DEXA (11-15). ADP and DXA methods are not recommended to assess FM and PBF in pediatrics because these methods are time-consuming, expensive, and require expert personnel (10). BIA is also an appropriate and valid method to evaluate PBF. However, BIA is not affordable in community studies, clinics, and screening programs due to its high cost (14,15). Therefore, most of the studies conducted

on children and adolescents that investigate problems related to overweight and obesity use international body mass index (BMI) references based on age and sex (16). To the best of our knowledge, there is currently a dearth of studies in Iran that have sought to estimate the PBF and FM in the pediatric and adolescent populations. Undertaking such research could significantly contribute to public health surveillance, enhance the identification of clinical conditions, and advance the field of research related to the prevention of overweight and obesity within clinical and epidemiological contexts. (16). The anthropometric measurements, which are indirect indicators of adiposity, are economical and nonintrusive (17,18). Thus, using a simple, practical, affordable method such as an anthropometry equation to estimate FM and PBF could be useful in the pediatric population.

In this study, we focused on the prediction of FM and PBF with anthropometric indices. Most studies on anthropometric indices in the Iranian population are related to adults (19-21). There is little evidence on the prediction of FM and PBF using anthropometric indices in Iranian children and adolescents. Therefore, this study aimed to develop and validate a simple equation to FM and PBF in children and adolescents.

Methods

Subjects

This cross-sectional study was conducted on 404 children (5-11 year old) and adolescents (11-18 year old) from January 2020 to November 2020 in Ahvaz, Iran. The sample size for this study was calculated using the body fat percentages measured in children and adolescents with the InBody BIA method, as reported in the study by Zheng et al (22) conducted on the Iranian population. The mean body fat percentage in that study was 24.90, with a standard deviation of 6.2. The sample size was computed using the following formula: N = [(Z1-α/2) 2 × sd2]/d2 (α = 0.05, confidence level of 95% and d = 0.35), and the result was 368. Considering the withdrawal rate of 10%, 404 subjects were recruited. The exclusion criteria were excess body weight secondary to causes other than high caloric intakes, such as growth hormone deficiency, syndromic obesity, hypothyroidism, long-lasting treatment with corticosteroids or other drugs that could influence energy intake or expenditure such as insulin, precocious puberty, having sedentary life due to neurologic or neuromuscular disorders, hypertension, renal disease, and edema. All participants were physically healthy.

Participants

Participants were randomly divided into two subgroups, i.e., derivation and validation. As has been suggested by Heyward and Wagner (23) and frequently used in the literature (24,25), the predictive equations' methodology includes the separation of the population sample into 2:3 and 1:3 ratios for development and validation groups, respectively. No significant differences were observed between the two groups in terms of age, sex, height, weight, BMI, FM, and PBF. There were 279 and 125 participants in the extraction and validation groups, respectively (Table 1). Derivation and validation groups included two-thirds and one-third of the samples, respectively. Then, FM and PBF predictive equations were derived from the derivation group and validated on the second group. To

Table 1. General characteristics, fat mass, and percentage of body fat values in all participants and derivation and validation groups

Variables	All (n = 404)	Derivation group (n = 279)	Validation group (n = 125)	*P* value*
Gender				0.73
Males (%)	176 (43)	120 (43)	56 (45)	
Females (%)	228 (57)	159 (57)	69 (55)	
Age (y)	12.37 ± 3.59	12.30 ± 3.58	12.54 ± 3.63	0.53
5–11 years old (%)	134 (33)	96 (34)	38 (30)	
11–18 years old (%)	270 (67)	183 (66)	87 (60)	
Height (cm)	154.40 ± 19.27	154.44 ± 19.37	154.33 ± 19.12	0.96
Weight (kg)	65.23 ± 29.54	65.91 ± 30.35	63.72 ± 27.70	0.49
BMI (kg/m2)	25-91 ± 7.62	26.14 ± 7.85	25.38 ± 7.09	0.35
BMI/age	80.67 ± 29.91	81.28 ± 29.44	79.30 ± 31.01	0.53
Normal weight (%)	114 (28)	77 (28)	37 (30)	
Overweight (%)	68 (17)	46 (16)	22 (17)	
Obesity (%)	222 (55)	156 (56)	66 (53)	
FM (kg)	24.12 ± 15.48	24.59 ± 15.85	23.06 ± 14.62	0.34
PBF (%)	34.38 ± 11.53	34.74 ± 11.47	33.55 ± 11.66	0.33

Abbreviations: n, number of participants; SD, standard deviation; FM, fat mass measured by BIA; PBF, percentage of body fat measured by BIA; BMI, body mass index.
Data are expressed as mean ± SD or number (%)
*t-test between derivation and validation groups. *P* value < 0.05 were set as significant.

ensure the correctness of the predictive equation, the formula was validated on all data.

Anthropometric measurements

Anthropometric assessments were performed based on international recommendations by a trained nutritionist (26). Participants were weighed in light clothing and barefoot by a mechanical scale (Seca, Hamburg, Germany) to the nearest 0.1 kg. Height was measured to the nearest 0.1 cm using a stadiometer portable measuring scale (Seca, Hamburg, Germany).

Body composition assessment

Body composition and FM and PBF were measured by a segmental multi-frequency bioelectrical impedance analyzer (InBody 770©; Biospace, Seoul, South Korea) and based on three accurate, reliable frequencies (14,15).

Accurate measurement of BIA was performed using its instructions carefully. Instructions demanded the following conditions before measurement: at least eight hours fasting status, no strenuous exercise for 12 hours, no walking at least for three hours, empty bladder, no consumption of alcohol, energy drinks, or caffeine, and having no metal devices (27,28). The age, gender and height of all participants were inserted in the BIA device separately. Then, participants were asked to stand on the BIA analyzer by following the instructions, including no movement, light clothing, bare feet placed entirely on the machine, and the electrodes held by both hands. Therefore, FM and PBF were estimated by an algorithm that included height, weight, age, and gender.

Statistical analysis

Descriptive statistics were presented as mean and standard deviation (SD) for continuous variables and proportions for categorical variables. The Kolmogorov–Smirnoff test was conducted to determine the normality of data distribution. An independent sample t-test was used to compare the results between derivation and validation groups. Pearson's correlation was calculated to assess the relationship between dependent variables and weight, height, BMI, sex, and age.

Simple linear regression of each variable for FM and PBF estimation by BIA was performed to select the most appropriate variables to run the multivariable analysis. This step was based on the power of each relationship. Multiple linear regression was used to generate equations for predicting FM and PBF based on FM and PBF calculated by BIA. Keeping in view routine clinical practice, we considered the following variables: age, weight, height, sex, and BMI. Additionally, we searched the highest R, R^2 value, and the lowest standard error of the estimate (SEE) values of each set of stepwise regression.

The degree of concordance regressions by the reference method (BIA) was analyzed by calculating Pearson's correlation coefficient (r). Furthermore, it was analyzed using the Bland-Altman method graphically.

Bland-Altman plots (29) were used to explore the distributions of systematic and random errors and determine agreement levels between the predicted and observed FM and PBF. The simplest derived predictive equation was validated in the validation sample. The SEE was used to define the accuracy of predictive equations. Furthermore, the limits of agreement (LOA) between the BIA measurement and predictive equation were investigated. A confidence interval of 95.0% was considered. Scatter plots were used to evaluate the correlation coefficient between observed and predicted FM and PBF. The coefficient of variation was calculated to achieve the predicting dispersion. We analyzed the difference between the BIA-estimated and predicted FM and PBF by the one-sample t-test. Paired samples t-tests were used to investigate the agreement between the BIA-estimated and predicted FM and PBF. Also, the mean difference and LOA were calculated between the predicted and observed FM and PBF. In addition, 95% LOA was calculated as the mean difference ± 1.96 standard deviations. The IBM SPSS Statistics 25.0 (IBM, Chicago, IL, USA) was used for the statistical analysis.

Results

Characteristics of the participants

Table 1 shows the characteristics of participants included in the derivation and validation samples. No significant differences were observed between the groups. Participants comprised 33% of children (6-11 years) and 67% of adolescents (11-18 years). Also, 43% and 57% of the participants were male and female, respectively.

Model predictors

Table 2 shows the correlation between measured FM and PBF and potential predictors, including age, sex, weight, height, and BMI. Predictors that were significantly correlated with FM and PBF were age, sex, weight, height, and BMI in all participants, except for age in the validation sample.

Derivation study

Linear regressions of each variable against FM, evaluated by BIA, are summarized in Table 3. The most powerful predictive equation for body fat mass of participants included variables such as sex, height, body weight, height, and BMI model 8 had the highest adjusted R^2 and the lowest SEE ($R^2 = 0.94$, SEE = 3.74 kg). The selected predictive equation based on the derivation group was:

FM (kg) = Weight (Kg) x 0.15 + BMI x 1.53 + Sex x 3.40 – Age (years) x 0.37 – 26.20; where sex = 1 for female and 0 for male.

Also, linear regressions of each variable against body fat percentage, evaluated by BIA, are summarized in Table 3.

Table 2. Correlation between variables, fat mass, and percentage of body fat in all participants and derivation and validation groups

	All	Derivation group	Validation group
FM			
Weight (kg)	0.90**	0.90**	0.89**
Height (cm)	0.56**	0.56**	0.57**
BMI (kg/m2)	0.96**	0.96**	0.95**
Sex	-0.13**	-0.11**	-0.17**
Age	0.45**	0.45**	0.46**
PBF			
Weight (kg)	0.50**	0.49**	0.51*
Height (cm)	0.14**	0.14*	0.15
BMI (kg/m^2)	0.73**	0.73**	0.74**
Sex	0.17*	0.18*	0.13*
Age	0.09*	0.10*	0.06

Abbreviations: FM, fat mass (kg); PBF, percentage of body fat; BMI, body mass index.
*Significant correlation of *P* value < 0·05 (2-tailed).
**Significant correlation of *P* value < 0·001(2-tailed).

The most powerful predictive equations for participants' body fat mass were sex, height, body weight, and BMI. The model 10 had the highest adjusted R2 and the lowest SEE (R2 = 0.82, SEE = 4.88 (kg). The selected predictive equation based on derivation group was:

PBF (kg) = 0.31 x Height (cm) - Weight (Kg) x 0.59 + BMI x 2.98 + Sex x 6.17 – Age (years) x 0.76 – 52.84; where sex = 1 for female and 0 for male.

Table 4 shows the correlation between FM and PBF estimated by equation and referenced FM and PBF (measured by BIA). The linear correlations between FM and PBF according to total, males, females, children, and adolescents showed a high degree of correlation in all categories (R = 0.96 for FM in all participants and R = 0.89 for PBF in all participants); moreover, the results remained consistent in total, males, females, children, and adolescents. Thus, there was a strong correlation between FM and PBF derived by the equation and the reference.

The equation was also validated on all study participants. It accurately estimated FM and PBF in the two groups (derivation and validation) and total participants

Table 3. Models for estimating fat mass and percentage of body fat based on descriptive characteristics

	β					(Constant)	R	R^2	SEE
	Weight	Height	BMI	Sex	Age				
FM									
Model 1	0.68**	-0.40**	-	-	-	42.77	0.94	0.89	5.06
Model 2	0.68**	-0.40**	-	-	-0.04	42.17	0.94	0.89	5.07
Model 3	0.70**	-0.40**	-	4.25**	-	34.03	0.95	0.91	4.64
Model 4	-	-	1.95**	-	-	-26.42	0.96	0.93	4.08
Model 5	-	-	1.94**	-	0.03	-26.68	0.96	0.93	4.09
Model 6	-	-	1.98**	2.54**		-31.27	0.97	0.94	3.89
Model 7	-	-	1.97**	2.55**	0.04	-31.59	0.97	0.94	3.90
Model 8	0.15**	-	1.53**	3.40**	-0.37**	-26.20	0.97	0.94	3.74
Model 9	-	0.06*	1.94**	2.87**	-0.23	-38.20	0.97	0.94	3.87
Model 10	0.20**	-0.06	1.42**	3.37**	-0.25	-18.40	0.97	0.94	3.74
PBF									
Model 1	0.42**	-0.45**	-	-	-	77.36	0.67	0.45	8.54
Model 2	0.42**	-0.39**	-	-	-0.38	71.86	0.67	0.45	8.53
Model 3	0.45**	-0.44**	-	7.83**	-	61.25	0.74	0.55	7.69
Model 4	-	-	1.07**	-	-	4.14	0.73	0.53	7.83
Model 5	-	-	1.30**	-	- 1.12**	14.32	0.79	0.63	6.98
Model 6	-	-	1.17**	8.12**		-8.69	0.80	0.65	6.77
Model 7	-	-	1.40**	7.98**	0.71**	-1.03	0.86	0.74	5.81
Model 8	-3.51**	-	2.42**	6.02**	-0.12	-13.41	0.89	0.79	5.20
Model 9	-	-0.06	1.43**	7.65**	-2.11**	5.78	0.86	0.74	5.79
Model 10	-0.59**	0.31**	2.98**	6.17**	-0.76**	-52.84	0.90	0.82	4.88

Abbreviations: FM, fat mass; PBF, percentage body fat; BMI, body mass index; Sex, male = 1, female = 0; β, beta coefficient; R^2, adjusted coefficient of determination; SEE, standard error of the estimate.
*Significant correlation of *P* value < 0·05 (2-tailed).
**Significant correlation of *P* value < 0·001(2-tailed).

according to gender and age (Table 5); there were no significant differences between FM and PBF achieved by equation and referenced FM and PBF (P Value > 0.05 in all subgroups).

Table 6 displays that the prediction equation had a small difference in means and agreement limits. In other words, the estimations by prediction equation of FM and PBF showed a small dispersion when compared with referenced FM and PBF (measured by BIA); moreover, the results remained consistent in males, females, children, and adolescents.

The distribution of systematic and random errors was evaluated by the Bland-Altman plot. The Bland–Altman graphics showed that the prediction equations of FM and PBF had a small difference in means and tight agreement limits in total participants. The scatter plot showed a good correlation between assessed and predicted FM and PBF in all participants' samples (Figures 1, 2).

Table 4. Determination of equation accuracy in participants using linear correlation

	All participants	Derivation group	Validation group
FM			
Total	0.96**	0.97**	0.95**
Males (%)	0.96**	0.96**	0.94**
Females (%)	0.97**	0.97**	0.97**
5–11 years old (%)	0.96**	0.97**	0.97**
11–18 years old (%)	0.97**	0.96**	0.95**
PBF			
Total	0.89**	0.90**	0.86**
Males (%)	0.88**	0.90**	0.86**
Females (%)	0.90**	0.90**	0.90**
5–11 years old (%)	0.92**	0.92**	0.93**
11–18 years old (%)	0.87**	0.89**	0.84**

Abbreviations: FM, fat mass; PBF, percentage of body fat; R, Pearson linear correlation coefficient.

Discussion

This study aimed to achieve simple and practical equations for an accurate estimation of FM and PBF in Iranian children and adolescents. To the best of our knowledge, no similar study carried out on children and adolescents was found. Furthermore, there were few studies in this field conducted in the Middle East and North Africa (MENA) (30, 31). Different models were used to estimate body fat percentage and total fat. Model 8 for estimating total fat and Model 10 for estimating fat percentage displayed the highest determination coefficient and the lowest SEE. In terms of the estimate of total fat, model 8 and model 10 were equal in R2 and SEE. Since the calculation of Model 8 was simpler than Model 10, model 8 was chosen as the final model. BMI, height, weight, age, and sex were considered in these models.

Several studies reported that although BMI correlated significantly with BF%, it could not be a precise predictive variable for BF% (32-34). It is indicated that the accuracy of the equations improves when other variables, such as sex and age, are considered in the analysis (35, 36). Hastuti et al. found that considering sex along with BMI might be more useful to improve the variability and LOA in the equations compared to BMI alone (33). Several studies have included skinfold thickness as one of the variables in their models for estimating FM and PBF. However, skinfold thickness is not recommended because of the difficulty of its measurement, especially in children (30).

The proposed equations showed an adequate level of agreement when compared to the BIA reference method. Ninety-five percent confidence intervals were relatively

Table 5. Validation of FM and PBF derived from the equation on all participants and subgroups

Variables	All participants			Derivation group			Validation group		
	Mean ± SD BIA	Mean ± SD equation	*P* value*	Mean ± SD BIA	Mean ± SD equation	*P* value*	Mean ± SD BIA	Mean ± SD equation	*P* value*
FM									
Total	24.12 ± 15.48	23.96 ± 14.86	0.42	24.59 ± 15.85	24.47 ± 15.33	0.57	23.06 ± 14.62	22.83 ± 13.75	0.56
Males	26.48 ± 18.24	24.04 ± 17.21	0.24	26.75 ± 19.22	26.60 ± 18.42	0.73	25.91 ± 16.10	24.84 ± 14.34	0.15
Females	22.29 ± 12.70	22.36 ± 12.57	0.72	22.97 ± 12.56	22.86 ± 12.33	0.61	20.74 ± 12.97	21.20 ± 13.12	0.18
5–11 years old	14.51 ± 9.12	15.14 ± 10.23	0.07	14.56 ± 9.49	14.90 ± 10.58	0.20	14.39 ± 8.25	15.75 ± 9.39	0.06
11–18 years old	28.89 ± 15.78	28.34 ± 14.87	0.08	29.86 ± 16.00	29.49 ± 15.07	0.23	26.84 ± 15.21	25.93 ± 14.24	0.07
PBF									
Total	33.55 ± 11.66	33.10 ± 9.80	0.39	34.38 ± 11.53	33.99 ± 10.25	0.13	34.74 ± 11.47	34.39 ± 10.44	0.22
Males	32.10 ± 12.99	31.27 ± 10.97	0.07	32.25 ± 13.12	31.92 ± 11.77	0.52	31.78 ± 12.84	30.18 ± 8.97	0.06
Females	36.13 ± 9.94	36.09 ± 9.13	0.88	36.63 ± 9.68	36.25 ± 8.90	0.26	34.99 ± 10.48	35.72 ± 9.72	0.19
5–11 years old	33.06 ± 11.19	32.93 ± 9.72	0.72	33.01 ± 11.25	32.48 ± 9.90	0.23	33.20 ± 11.20	34.06 ± 9.27	0.20
11–18 years old	35.03 ± 11.66	34.52 ± 10.48	0.13	35.65 ± 11.52	35.39 ± 10.60	0.48	33.71 ± 11.91	32.68 ± 10.04	0.13

Abbreviations: FM, fat mass (kg); PBF, percentage body fat; BIA, bioelectrical impedance analysis; SD, standard deviation.
* Differs significantly ($P < 0.05$) paired *t* test.

Table 6. Mean difference and LOA between FM and PBF derived from equation and referenced FM and PBF

Variables	All participants		Derivation group		Validation group	
	Mean difference ± SD (kg)	LOA (kg) (lower, upper)	Mean difference ± SD (kg)	LOA (kg) (lower, upper)	Mean difference ± SD (kg)	LOA (kg) (lower, upper)
FM						
Total	0.15 ± 3.89	7.79, -7.48	0.12 ± 3.71	7.40, -7.15	0.22 ± 4.29	8.64, -8.20
Males	0.44 ± 5.00	10.25, -9.37	0.14 ± 4.75	9.47, -9.17	1.06 ± 5.49	11.82, -9.69
Females	-0.06 ± 2.74	5.32, -5.45	0.10 ± 2.68	5.37, -5.16	-0.46 ± 2.86	5.15, -6.08
5–11 years old	-0.62 ± 2.54	4.36, -5.62	-0.33 ± 2.57	4.71, -5.39	-1.35 ± 2.34	8.55, -7.81
11–18 years old	0.54 ± 4.37	9.11, -8.02	0.36 ± 4.17	3.24, -5.96	0.91 ± 4.76	10.24, -8.42
PBF						
Total	0.38 ± 5.16	10.51, -9.74	0.35 ± 4.84	9.84, -9.13	0.45 ± 5.85	11.92, -11.01
Males	0.82 ± 6.07	12.74, -11.08	0.32 ± 5.62	11.35, -10.70	1.09 ± 6.88	15.38, -11.58
Females	0.04 ± 4.31	8.50, -8.42	0.37 ± 4.16	8.54, -7.79	-0.72 ± 4.58	8.26, -9.71
5–11 years old	0.12 ± 4.23	8.43, -8.17	0.52 ± 4.23	8.82, -7.78	-0.86 ± 4.13	7.23, -8.95
11–18 years old	0.50 ± 5.57	11.43, -10.41	0.26 ± 5.13	10.33, -9.80	1.02 ± 6.39	13.56, -11.51

Abbreviations: FM, fat mass (kg); PBF, percentage of body fat; BIA, bioelectrical impedance analysis; SD, standard deviation; LOA, limits of agreement.

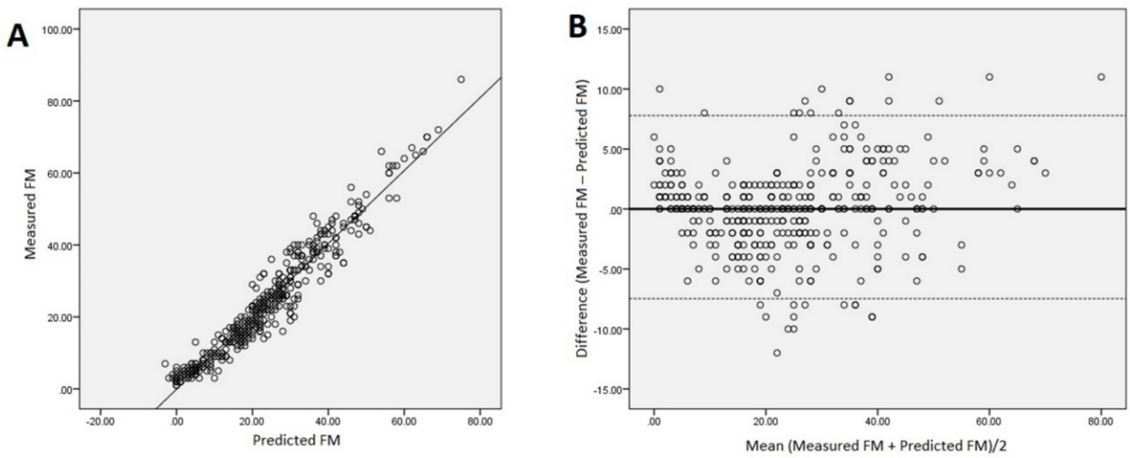

Figure 1. Total sample analysis. (A) Scatter plot of bioelectrical impedance analysis (BIA)-measured (Y-axis) against estimated fat mass (X-axis); (B) Bland-Altman plot of difference between predicted and BIA-measured fat mass (Y-axis) against their mean (X-axis). Bland-Altman graphics showed that the prediction equations of FM had a small difference in means and tight agreement limits in total participants. The scatter plot showed a good correlation between assessed and predicted FM in all participants ' samples

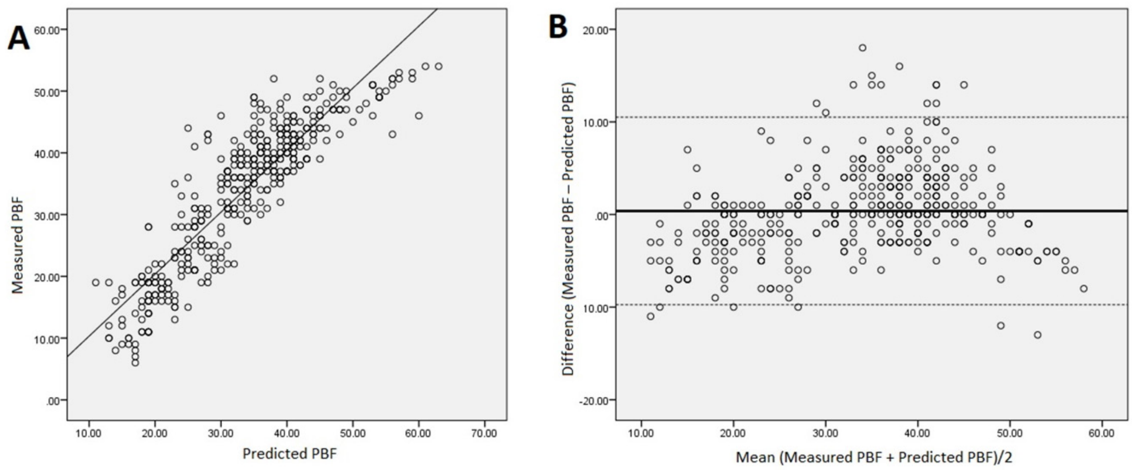

Figure 2. Total sample analysis. (A) Scatter plot of bioelectrical impedance analysis (BIA)-measured (Y-axis) against estimated percentage body fat (X-axis); (B) Bland-Altman plot of difference between predicted and BIA-measured percentage body fat(Y-axis) against their mean (X-axis). The distribution of systematic and random errors was evaluated by the Bland-Altman plot. The Bland - Altman graphics showed that the prediction equations of PBF had a small difference in means and tight agreement limits in total participants. The scatter plot showed a good correlation between assessed and predicted PBF in all participants ' samples

narrow, and also correlation coefficients between 0.94 and 0.97 for FM and between 0.84 and 0.93 for PBF in all participants were significant.

Furthermore, correlation coefficients indicated high agreement levels for FM and PBF in derivation and validation groups. High levels of agreement were observed in the two groups (derivation and validation) and total participants in males, females, children, and adolescents. In addition, no significant differences were observed between the reference method (BIA) and the equations in the males, females, children, adolescents, and all populations in the two groups and total participants. These results suggest that the prediction of FM among Iranian children and adolescents is adequately accurate.

BIA is highly correlated with DEXA, ADP and deuterium dilution as reference methods in children and adolescents (11-15). Thus, BIA has been considered a reference technique for measuring FM and PBF based on different age groups in several studies (37-40). Lyra et al measured the FM of 218 Brazilian adolescents using BIA, and the FM estimation formula was developed using this measurement (40).

Expensive equipment (MRI, DXA, BIA) or trained professionals for collecting accurate measurements (e.g., skinfold thickness) are not required for the equations of this study. Following standard protocols is not always possible in children and adolescents (41). In addition, some of these techniques are time-consuming and need working with radiation (e.g., DXA) (42). Our proposed method only requires a scale and a stadiometer, which are available in all clinical settings. Moreover, our findings can be implemented in an e-health application freely downloaded on smartphones, tablets, and computers, which is easy to use for professionals (i.e., doctors, nutritionists, dieticians, etc). Overall, the primary goal of our method is healthcare improvement through the optimization of patient care and a reduction in healthcare costs (43).

Furthermore, FM and PBF measurements can be applied to identify children and adolescents with higher risk factors of type 2 diabetes mellitus, cardiovascular disease, hypertension, cancer (44), and psychosocial disorders due to excessive body fat (45). Therefore, these measurements can be used as indicators of health and well-being that reflect the nutritional status and living conditions.

The current study was the first study in this field conducted on Iranian children and adolescents. Also, this study had a wide age range (5.0-18.9 years old). However, this study had some limitations, including the lack of DXA measurement as the gold standard method for measuring FM and PBF. Although BIA is not considered a gold standard for assessing FM and PBF, several studies have shown high accuracy and reliability of body composition measured by BIA compared with DXA in children and adolescents (11-15). Additional limitations of this study encompassed the omission of accounting for the menstrual status of female subjects and the absence of internal validation through the bootstrap methodology.

Conclusion

Our study was conducted to explore an accurate and easy method to use an equation capable of estimating FM and PBF with a high degree of agreement in children and adolescents. Using estimated equations is not expensive and time-consuming; these equations can be used for patients by health professionals (e.g., medical doctors, nutritionists, dieticians) in clinical settings (e.g., outpatient clinics) where advanced tools such as MRI, CT, DXA, and BIA are not available.

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Competing Interests

The authors declare that there is no conflict of interest.

Ethical Approval

The informed consent form was signed by all participants. This descriptive-analytical study was approved by the Ethical Committee of Ahvaz Jundishapur University of Medical Sciences, Iran (Ethics Code: IR.AJUMS.REC.1400.276).

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