Nutrición Hospitalaria

Original

Anthropometric methods for obesity screening in schoolchildren; the Ouro Preto Study

A. P. C. Cándido[1], J. P. S. Alosta[2], C. T. Oliveira[2], R. N. Freitas[3], S. N. Freitas[3] and G. L. L. Machado-Coelho[2]

[1]Departamento de Nutrição. Universidade Federal de Juiz de Fora. Juiz de Fora. MG. Brazil. [2]Laboratório de Epidemiologia. Departamento de Ciências Médicas. Universidade Federal de Ouro Preto. Ouro Preto. MG. Brazil. [3]Departamento de Nutrição Clínica e Social. Universidade Federal de Ouro Preto. Ouro Preto. MG. Brazil.

Abstract

Background and aims: Childhood obesity is increasing dramatically in last decades. To evaluate the usefulness of body mass index (BMI), skinfold thickness (ST), waist circumference (WC), and foot-to-foot bioelectrical impedance (BIA-FF) for screening for obesity in mixed-race population, using the tetrapolar bioelectrical impedance (BIA-T) technique as reference method.

Methods and results: A cross-sectional-based population study was performed in the city of Ouro Preto, Brazil, in 2006. Schoolchildren aged 6-15 years (n = 788) was randomly selected according to age and sex stratified by the proportion of students in each schools of the city. Nonparametric receiver operating characteristic (ROC) analysis was used to define the sensitivity and specificity for each method studied using the tetrapolar method as reference. The BMI and the BIA-FF were the most suitable for adiposity screening in pre-pubertal and pubertal stages because they present a better balance between sensitivity and specificity, and smaller misclassification. For post-pubertal boys, the BF-ST-D was the best body fat assessment method.

Conclusion: The results suggest that BIA-FF and BMI are choice methods for obesity screening in mixed population and that the method choice for body fat screening must be done according to sexual maturity of boys and girls. The present study demonstrates the need to perform studies in wider mixed-race population to determine anthropometric parameters and to examine the predictive ability of methods and cut-offs here elucidated in the development of obesity.

(*Nutr Hosp.* 2012;27:146-153)

DOI:10.3305/nh.2012.27.1.5421

Key words: *Obesity. Bioelectrical impedance. Sensibility. Specificity. Schoolchildren.*

Correspondence: Ana Paula Carlos Cândido.
Departamento de Nutrição. Instituto de Ciências Biológicas.
Universidade Federal de Juiz de Fora.
Rua José Lourenço Kelmer, s/n.
Campus Universitario, Bairro São Pedro.
CEP: 36036-330 Juiz de Fora, MG, Brazil.
E-mail: anapaula.candido@ufjf.edu.br

MÉTODOS DE ANTROPOMETRÍA PARA LA DETECCIÓN DE OBESIDAD EN ESCOLARES; EL ESTUDIO DE OURO PRETO

Resumen

Antecedentes y objetivos: La obesidad infantil está aumentando alarmantemente en las últimas décadas. Para evaluar la utilidad del índice de masa corporal (IMC), el grosor del pliegue cutáneo (GPC), la circunferencia de la cintura (CC), y la impedancia bioeléctrica pie-a-pie (BIA-PP) para el cribado de la obesidad en poblaciones con diversidad de razas utilizando una técnica de impedancia bioeléctrica tetrapolar (BIA-T) como el método de referencia.

Métodos y resultados: se realizó un estudio transversal poblacional en la ciudad de Ouro Preto, Brasil, en el 2006. Se distribuyó al azar a escolares de 6-15 años (n = 788), que se seleccionaron en función de la edad y el sexo, estratificados por la proporción de estudiantes en cada colegio de la ciudad. Se utilizó un análisis no paramétrico de curvas ROC para definir la sensibilidad y la especificidad para cada método estudiado empleando el método tetrapolar como referencia. El IMC y la BIA-PP fueron los más idóneos para el cribado de la obesidad en las etapas prepuberales y puberales puesto que presentan un equilibrio mejor entre la sensibilidad y la especificidad y un menor fallo de clasificación. Para los niños prepúberes, el BF-GPC-D fue el mejor método de evaluación de la grasa corporal.

Conclusión: Los resultados sugieren que la BIA-PP y el IMC son los métodos de elección para el cribado de la obesidad en poblaciones mixtas y que el método de elección para el cribado de la grasa corporal debe realizarse de acuerdo con la madurez sexual de los chicos y chicas. Este estudio demuestra la necesidad de realizar estudios en poblaciones mixtas más amplias para determinar los parámetros antropológicos y examinar la capacidad predictiva de los métodos y los puntos de corte obtenidos aquí en el desarrollo de la obesidad.

(*Nutr Hosp.* 2011;27:146-153)

DOI:10.3305/nh.2012.27.1.5421

Palabras clave: *Obesidad. Impedancia bioeléctrica. Sensibilidad. Especificidad. Escolares.*

Introduction

Adult obesity is viewed as a public health issue in several countries, changing the epidemiologic profile of morbidity and mortality,[1] as it favours the occurrence of chronic and non-transmissible diseases.[2] In the last decades, it also has been afflicting children and teenagers in several countries,[2] including Brazil.[3] Obese children and teenagers are likely to remain obese in their adult life,[4] and the consequences of obesity, such as high blood pressure, dyslipidemia, and insulin resistance, may occur even in childhood.[1,5] The early detection and intervention may reduce obesity in childhood and in later stages of life, consequently reducing associated diseases.[6] However, the great obesity dilemma at that stage is the adoption of diagnosis criteria to define excess body fat, because the growth and development of several tissues and body compartments (such as bone tissue, muscle tissue, adipose tissue, and total body water) and sexual maturity[7] make it difficult to set anthropometric standards.[8] In addition to those limiting factors, other elements complicate the setting of such standards, such as the fact that the parameters are restricted to certain age groups and race/ethnicity and are usually determined through punctual studies and therefore recommended for the population for which they were determined.[9] Thus, there is not an international recommendation regarding the cut-off for body fat that defines the nutritional risk in the age group of 6-15 years, especially in mixed-race population. At the same time, because of the high association between obesity and non-transmissible diseases, methods studies and easy-to-run, accessible equipments, which can offer reliable results and define diagnostic criteria and the screening of individuals in risk, become more and more necessary. Thus, the goal of this study was to determine the sensitivity and specificity of the body mass index, body fat estimated by skinfold thickness, body fat estimated by bipolar foot-to-foot bioelectrical impedance technique, and waist circumference for the definition of body fat excess, in relation to the reference method tetrapolar bioelectrical impedance technique, to validate those tools for the body composition assessment of a Brazilian paediatric mixed-race population.

Methods

Study area and population

The city of Ouro Preto, located in the metallurgic region of Minas Gerais in the Southern Brazil, has 5,963 children (6-9 years old) and 4,897 adolescents (10-14 years old) attending all schools in the urban area[10].

Subjects and study design

A cross-sectional survey was conducted among schoolchildren chosen by simple random selection according to age, gender, and stratified by proportion of students in classes at all 15 state and two public schools. The sample size (n = 850) was calculated using the following premises: overweight prevalence (8%);[11] precision of 2%; 20% of losses; 90% of power and 5% of significant level. Children with special needs were not included in this study.

Reference method

The reference method used for definition of obesity was tetrapolar bioelectrical impedance technique (BIA-T). Resistance and reactance values were provided by Quantum II BIA-T (RJL Systems Inc., Michigan, USA), and fat mass was derived using the software for children available on the BIA machine. All subjects refrained from eating, drinking, and exercising for 6 h before testing. Subjects were tested in the supine position with arms and legs abducted from the body. Shoes and socks were removed and contact areas were scrubbed with alcohol immediately before electrode placement. Source electrodes were placed proximal to the metacarpo-phalangeal joint on the dorsal surface of the right hand and distal to the transverse arch on the superior surface of the right foot. Sensor electrodes were placed at the midpoint between the distal prominence of the radius and ulna of the right wrist, and between the medial and lateral malleoli of the right ankle. Resistance and reactance were recorded to the nearest ohm. Obesity was defined by body fat percentage based on the 85th percentiles distribution. These percentiles were used, because at present, don't have body fat cut-off for Brazilian children and adolescents.

Anthropometric and body composition measurements

All data were collected simultaneously by a team of trained research assistants from March to December 2006. Anthropometric variables analyzed were weight, height, waist circumference (WC), skinfold thickness (ST), and body fat mass (BF). Weight and height were recorded using a TANITA BF542® (Tanita Corporation of America, Arlington Heights, IL, USA) scale and WCS stadiometer (Cardiomed, Curitiba, Brazil). Body mass index (BMI, kg/m²) and BMI z-score (SDS)[12] were derived. Waist circumference (WC) was measured midway between the lowest rib and the iliac crest with an inelastic tape to the nearest 1 mm. The measurement was made at the end of a normal expiration while the subject stood upright, with feet together and arms hanging freely at the sides. To assess subcutaneous fat, the skinfold thickness of the following sites was measured: suprailiac, subscapular, triceps, and biceps using Cescorf callipers (Cescorf Inc., Porto Alegre, Brazil). All measurements were made on the right side of the subject and obtained in triplicate by a team

of specially trained technicians. The average of three measures was calculated for each site, and equations were used to predict percent fat in accordance to Deurenberg et al, 1990[13] (BF-ST-D) and Slaugther et al, 1988[14] (BF-ST-S). The BF was estimated with bipolar foot-to-foot bioelectrical impedance (BIA-FF) technique using the Tanita® scale, with subjects stand erect on the platform without socks and metallic objects.

Sexual maturity and skin colour

Sexual maturity was available using a self-report questionnaire based on Tanner's criteria: pre-pubertal (1Tanner stage), pubertal (2-3 Tanner stage) and post-pubertal (4-5 Tanner stage).[15] Skin colour was available by using a self-report questionnaire.

Ethical aspects

This project was approved by the Institutional Review Board of the Federal University of Ouro Preto (Protocol Number 2004/46). Participation in the study was entirely voluntary: child consent and signed informed consent of the parents or legal guardians of each participant were obtained prior of the study.

Statistical analyses

The analyses were stratified by sex and sexual maturity, using BIA-T as the reference method. It were calculated the sensitivity (probability of detecting truly obese individuals) and specificity (probability of detecting truly not obese individuals) for each point of the different anthropometrics variables, and these index were plotting on the receiver operating characteristic (ROC) and compared by McNemar chi-square test. Youden index was used to measure the accuracy of diagnostic test. Differences between values were considered statistically significant for ρ values ≤ 0.05. Statistical analyses were carried out in SPSS software (version 13.0; SPSS Inc, Chicago, IL, USA).

Results

The demographic characteristics of the schoolchildren showed that total sample (n = 788) was composed of 52.3% girls and 47.7% boys, aged 6-15 years, being 162 (46.3%) pre-pubertal, 123 (51.5%) pubertal e 127 (62.9%) post-pubertal girls; 187 (53.7%) pre-pubertal, 116 (48.5 pubertal e 73 (37.1%) post-pubertal boys. In relation to skin colour, 615 students (82.0%) were auto-defined as mixed race, 110 (14.7%) as white, and 25 (3.3%) as black.

In table I are presented the anthropometric characteristics of the schoolchildren. All variables show the symmetrical distribution. In both girls and boys, weight, height, BMI, WC, and body fat generally increased significantly with age and sexual maturity, except BF-ST-S in boys.

In girls, body fat assessed by the BIA-T showed strong to weak correlation (r = 0.89 to r = 0.42; p = 0.01) with anthropometric variables, and with boys, moderate to weak correlation (r = 0.76 to r = 0.31; p = 0.01). We observed good correlation between BIA-T and BIA-FF (r ≈ 0.88; p = 0.01), and BMI (r ≈ 0.87; p = 0.01) and WC (r ≈ 0.84; p = 0.01), in pre-puberal e puberal girls; and only BIA-FF (r = 0.81; p = 0.01) in post-puberal girls. In boys, moderate correlation was observed between BIA-T and BIA-FF (r ≈ 0.74; p = 0.01), and BMI (r ≈ 0.74; p = 0.01) and WC (r ≈ 0.71; p = 0.01), in pre-puberal e post-puberal period; and only BIA-FF (r = 0.75; p = 0.01) in puberal boys. Heigth presented weak correlation in both genders in prepuberal and puberal period and no correlation in post-pubertal period (data not shown).

In table II are described the sensitivity values, specificity, false positive, false negative, and Youden index for the anthropometric variables regarding the BIA-T

Variables	Girls (mean ± SD)				Boys (mean ± SD)			
	Prepubertal	Pubertal	Postpubertal	p*	Prepubertal	Pubertal	Postpubertal	p*
Weight (kg)	27.8 ± 6.6	39.6 ± 12.3	51.3 ± 10.8	< 0.001	29.8 ± 8.3	39.5 ± 10.2	52.4 ± 11.8	< 0.001
Height (cm)	129.8 ± 10.0	143.3 ± 11.7	157.5 ± 5.9	< 0.001	132.0 ± 10.3	147.2 ± 9.8	161.0 ± 9.5	< 0.001
BMI (kg/m²)[a]	16.3 ± 2.2	18.9 ± 4.0	20.6 ± 3.7	< 0.001	16.8 ± 2.8	18.0 ± 2.8	20.0 ± 3.2	< 0.001
WC (cm)[b]	57.3 ± 6.5	64.7 ± 10.0	69.3 ± 9.3	< 0.001	59.1 ± 7.6	63.5 ± 8.2	70.1 ± 8.9	< 0.001
BIA-FF (%)[c]	23.5 ± 5.9	28.7 ± 8.1	31.5 ± 8.2	< 0.001	16.9 ± 7.7	18.6 ± 6.6	19.1 ± 7.3	0.04
BF-ST-S (%)[d]	16.3 ± 5.0	21.0 ± 8.9	23.1 ± 7.1	< 0.001	13.0 ± 7.9	13.8 ± 8.5	14.3 ± 9.0	0.45
BF-ST-D (%)[e]	18.1 ± 4.6	19.4 ± 5.0	21.5 ± 6.5	< 0.001	14.7 ± 4.6	15.3 ± 3.7	13.7 ± 3.9	0.03
BIA-T (%)[f]	15.0 ± 8.7	22.8 ± 9.7	27.2 ± 8.9	< 0.001	16.3 ± 8.5	18.5 ± 6.9	19.1 ± 7.0	0.009

[a]Body mass index; [b]waist circumference; [c]foot-to-foot bioelectrical impedance technique; [d]body fat by skinfold thickness in accordance Slaughter et al.[19]; [e]body fat by skinfold thickness in accordance Deurenberg et al.[18]; [f]body fat by tetrapolar bioelectrical impedance technique in accordance BIA machine. *t test.

Table II

Sensitivity, specificity, false positive, false negative and Youden index for each one of the anthropometric methods, and their respective cut-offs, using the BIA-T[a] as reference for obesity diagnosis[b], among schoolgirls in Ouro Preto, Minas Gerais, Brazil, 2006

Stage	Methods	Cutoff	N	Sensitivity (95% CI)	Specificity (95% CI)	p value[c]	FP[d] n (%)	FNe n (%)	J[f] (%)
	BMI (SDS)[g]	> 1.99	159	87.5 (47.4-97.9)	99.3 (96.3-99.9)	1.0	2 (1.3)	1 (12.5)	86.8
	WC (cm)[h]	> 61.0	157	100 (62.9-100)	80.3 (72.9-86.4)	< 0.001	33 (22.1)	0 (0)	80.3
Prepubertal	BIA-FF (%)[i]	> 28.5	159	100 (62.9-100)	83.2 (76.2-88.8)	< 0.001	26 (17.2)	0 (0)	83.2
	BF-ST-S (%)[j]	> 22.0	159	87.5 (47.4-97.9)	87.9 (81.6-92.7)	< 0.001	19 (12.6)	1 (12.5)	75.4
	BF-ST-D (%)[k]	> 26.6	158	80.0 (28.8-96.7)	97.5 (93.0-99.5)	0.18	7 (4.7)	2 (25)	77.5
	BMI (SDS)[g]	> 0.88	121	88.9 (70.8-97.5)	88.5 (80.4-94.1)	0.02	13 (13.8)	3 (11.1)	77.4
	WC (cm)[h]	> 67.0	121	92.6 (75.7-98.9)	97.9 (92.7-99.7)	0.07	7 (7.4)	1 (3.7)	90.5
Pubertal	BIA-FF (%)[i]	> 32.0	121	96.3 (81.0-99.4)	93.7 (86.9-97.7)	0.07	7 (7.4)	1 (3.7)	90.0
	BF-ST-S (%)[j]	> 25.0	121	92.6 (75.7-98.9)	92.7 (85.5-97.0)	0.34	7 (7.4)	3 (11.1)	85.3
	BF-ST-D (%)[k]	> 22.3	121	92.0 (73.9-98.8)	92.9 (85.3-97.3)	0.18	7 (7.4)	2 (7.4)	84.9
	BMI (SDS)[g]	> 0.44	123	78.0 (64.0-88.5)	84.9 (74.6-92.2)	1.0	12 (16.4)	11 (22.0)	62.9
	WC (cm)[h]	> 69.5	123	79.6 (65.7-89.7)	87.5 (77.6-94.1)	0.82	7 (9.6)	6 (12.0)	67.1
Pospubertal	BIA-FF (%)[i]	> 32.0	121	88.0 (75.7-95.4)	93.2 (84.7-97.7)	1.0	11 (15.3)	9 (18.4)	81.2
	BF-ST-S (%)[j]	> 21.1	123	90.0 (78.2-96.6)	64.4 (52.3-75.2)	< 0.001	28 (38.4)	5 (10.0)	54.4
	BF-ST-D (%)[k]	> 19.4	123	93.9 (83.1-98.6)	62.9 (49.7-74.8)	< 0.001	33 (45.2)	3 (6.0)	56.8

[a]Tetrapolar bioelectrical impedance technique; [b]Williams et al. (1991); [c]McNemar Test; [d]False positive; [e]False negative; [f]Youden index [(S+E)-1]; [g]Body Mass Index in standard deviation score; [h]waist circumference; [i]foot-to-foot bioelectrical impedance technique; [j]body fat by skinfold thickness in accordance Slaughter et al. (1988); [k]body fat by skinfold thickness in accordance Deurenberg et al. (1990).

in girls according to sexual maturity. Considering the balance between sensitivity and specificity of the different methods, we observed that only cutoffs of WC increased according to sexual maturity. In pre-pubertal stage, the methods presenting highest sensitivity (100%) were WC and BIA-FF, and highest specificity (99.3%) was BMI. BMI presenting smaller misclassification with a higher Youden index (86.8) and no difference between reference method (p = 1.0) being more suitable to detect excess body fat compared with the other methods. In pubertal stage, the methods presenting highest sensitivity (96.3%) was BIA-FF, being WC the most specific (97.9%). BIA-FF showed best balance between sensitivity and specificity, smaller misclassification (Youden index = 90.0), and no difference between reference method (p = 0.07). In post-pubertal stage, the methods with highest sensitivity (93.9%) in detecting obesity were BF-ST-D, and with most specificity (93.2%) was BIA-FF. Similar to pubertal stage, BIA-FF showed more suitable to detect excess body fat in post-pubertal stage (best balance sensitivity/specificity, Youden index = 81.2, and p = 1.0). In figure 1 are presented sensitivity and specificity of the different methods for obesity diagnosis among schoolchildren.

In table III are described the values of sensitivity, specificity, false positive, false negative, and Youden index for the anthropometric variables among boys according to sexual maturity. Only cutoffs of WC and BIA-FF increased according to sexual maturity. In pre-pubertal stage, the method with highest sensitivity (100%) were BIA-FF, BF-ST-S, and BF-ST-D; and with highest specificity (98.1%) was WC. However, BIA-FF showed that difference between reference

method revealed a better balance between sensitivity and specificity and smaller misclassification (Youden index = 96.2) when compared with the other methods. In pubertal stage, the methods presenting the highest sensitivity (100%) were BMI, BF-ST-S, and BF-ST-D. The methods with highest specificity (96.9%) were BIA-FF and WC. Similar to pubertal stage, BIA-FF was the method that presented best balance between sensitivity and specificity, being more suitable to detect excess body fat compared with the other methods (Youden index = 84.4 and p = 1.0). In post-pubertal stage, all methods presented high sensitivity (100%) except BMI, being this most specific (91.4%). The body fat percentage obtained through skinfold thickness using the Deurenberg predictive equation showed difference between reference method, however, was the method with best balance between sensitivity and specificity and smaller misclassification (Youden index = 91.4). In figure 1 are presented receiver operating characteristic curves for obesity diagnosis among schoolchildren.

Discussion

In this study, tetrapolar bioelectrical impedance analysis (BIA-T) was considered to be reference method to assess body fat percentage because it has shown a high correlation coefficient (r ≥ 94) in comparison to gold standard method of body composition assessment dual-energy X-ray absorptiometry (DXA).[16] Although BIA-T is a less accurate method compared with DXA, it can be used in epidemiology population
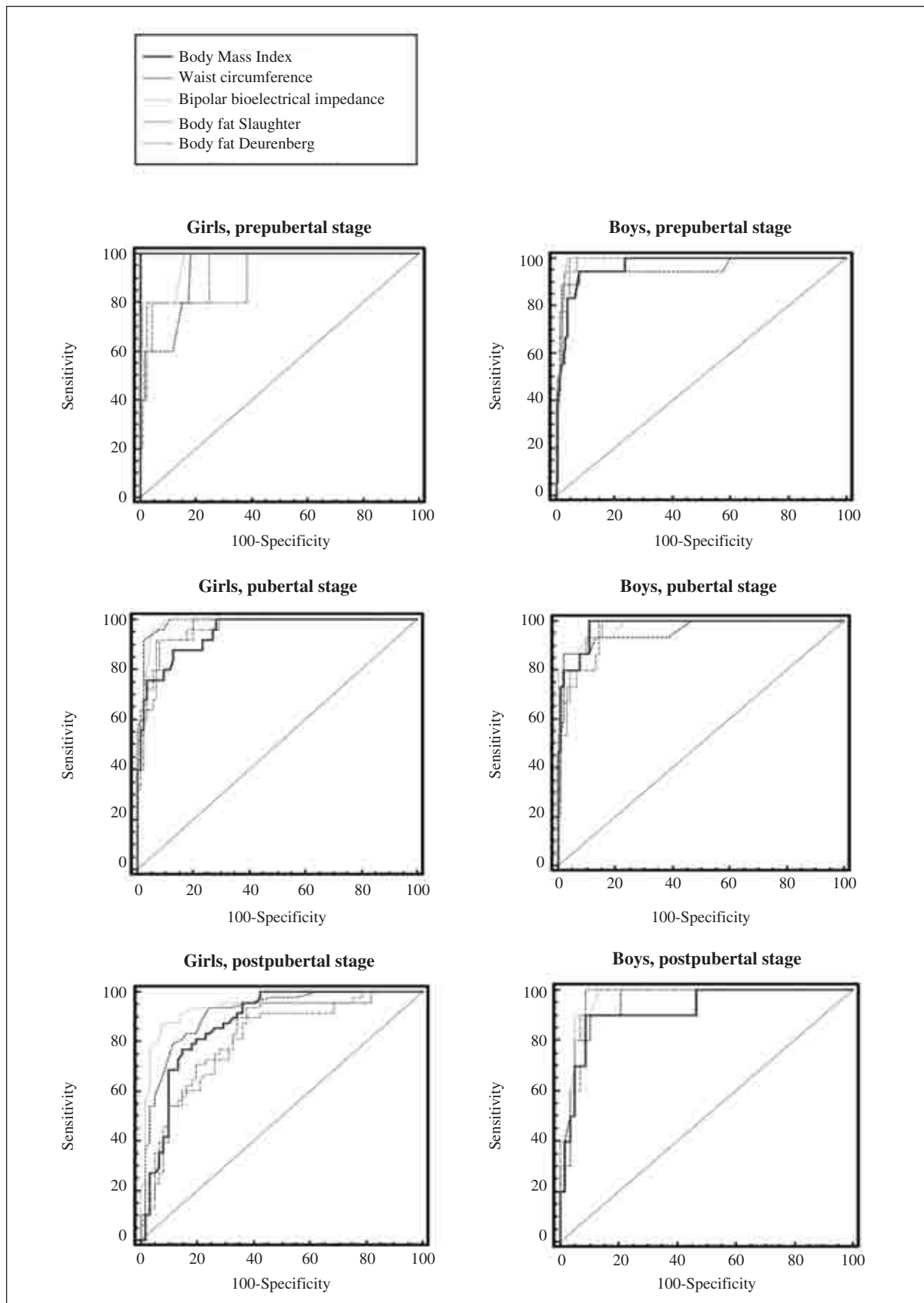
Legend:
- Body Mass Index
- Waist circumference
- Bipolar bioelectrical impedance
- Body fat Slaughter
- Body fat Deurenberg

Girls, prepubertal stage

Sensitivity / 100-Specificity

Boys, prepubertal stage

Sensitivity / 100-Specificity

Girls, pubertal stage

Sensitivity / 100-Specificity

Boys, pubertal stage

Sensitivity / 100-Specificity

Girls, postpubertal stage

Sensitivity / 100-Specificity

Boys, postpubertal stage

Sensitivity / 100-Specificity

Fig. 1.—Receiver operating characteristic curves for obesity diagnosis among schoolchildren in Ouro Preto, Minas Gerais, Brazil, 2006.

Table III

Sensitivity, specificity, false positive, false negative and Youden index for each one of the anthropometric methods, and their respective cut-offs, using the BIA-T[a] as reference for obesity diagnosis[b], among schoolboys in Ouro Preto, Minas Gerais, Brazil, 2006

Stage	Methods	Cutoff	N	Sensitivity (95% CI)	Specificity (95% CI)	p value[c]	FP[d] n (%)	FNe n (%)	J[f] (%)
Prepubertal	BMI (SDS)[g]	>1.01	183	95.0 (75.1-99.2)	92.0 (86.7-95.7)	0.001	14 (8.6)	1 (5.0)	87.0
	WC (cm)[h]	>65.0	181	90.0 (68.3-98.5)	98.1 (94.6-99.6)	0.29	6 (3.7)	2 (10.0)	88.1
	BIA-FF (%)[i]	>22.5	181	100 (83.0-100)	96.2 (92.0-98.6)	0.03	6 (3.7)	0 (0)	96.2
	BF-ST-S (%)[j]	>15.8	183	100 (83.0-100)	90.7 (85.2-94.7)	<0.001	16 (9.8)	0 (0)	90.7
	BF-ST-D (%)[k]	>19.0	183	100 (81.3-100)	95.4 (90.8-98.1)	0.004	9 (5.5)	0 (0)	95.4
Pubertal	BMI (SDS)[g]	>0.62	112	100 (79.2-100)	86.6 (78.2-92.7)	<0.001	14 (14.6)	0 (0)	86.6
	WC (cm)[h]	>69.5	112	87.5 (61.6-98.1)	96.9 (91.2-99.3)	0.69	4 (4.2)	2 (12.5)	84.4
	BIA-FF (%)[i]	>23.0	112	87.5 (61.6-98.1)	96.9 (91.2-99.3)	1.0	3 (3.1)	2 (12.5)	84.4
	BF-ST-S (%)[j]	>15.0	112	100 (79.2-100)	82.5 (73.4-89.4)	<0.001	17 (17.7)	0 (0)	82.5
	BF-ST-D (%)[k]	>16.7	112	100 (78.0-100)	84.4 (75.3-91.2)	<0.001	18 (18.8)	0 (0)	84.4
Pospubertal	BMI (SDS)[g]	>1.14	74	90.0 (55.5-98.3)	92.2 (82.7-97.4)	0.12	6 (9.4)	0 (10.0)	82.2
	WC (cm)[h]	>71.5	74	100 (69.0-100)	81.2 (69.5-89.9)	<0.001	15 (23.4)	0 (0)	81.2
	BIA-FF (%)[i]	>23.0	74	100 (69.0-100)	87.5 (76.8-94.4)	0.002	10 (15.6)	0 (0)	87.5
	BF-ST-S (%)[j]	>17.6	74	100 (69.0-100)	89.1 (78.7-95.5)	0.004	9 (14.1)	0 (0)	89.1
	BF-ST-D (%)[k]	>16.9	74	100 (69.0-100)	91.4 (81.0-97.1)	0.02	7 (10.9)	0 (0)	91.4

[a]Tetrapolar bioelectrical impedance technique; [b]Williams et al. (1991); [c]McNemar Test; [d]False positive; [e]False negative; [f]Youden index [(S+E)-1]; [g]Body Mass Index in standard deviation score; [h]waist circumference; [i]foot-to-foot bioelectrical impedance technique; [j]body fat by skinfold thickness in accordance Slaughter et al. (1988); [k]body fat by skinfold thickness in accordance Deurenberg et al. (1990).

studies because it is a portable device and easy to run and do not offer risks of radiation exposure, allowing a larger sample of children and teenagers. In this study, a good correlation between BIA-T and BMI, WC, and BIA-FF methods was observed, especially in girls. BMI and BIA-FF were the most suitable methods for obesity screening in this population because they present a higher positive likelihood ratio and a better balance between sensitivity and specificity.

Generally, the cutoffs for each method increased according to gender and sexual maturity, showing the interference of hormonal changes in body composition during puberty.[7,17,18] According to Díaz et al., 1996,[19] BMI increases significantly from 0.5 to 1.3 kg/m² in each sexual maturity stage in girls. Similarly, BMI increased steadily with age in boys, as soon as WC in both genders.[20] Thus, analyzing the body changes based only on chronological age may lead to oblique results because children of the same age do not necessarily present the same body standards.

BMI is an easy and reproducible body fat index, being validated in childhood by body composition methods.[21] In pre-pubertal stage, the use of BMI may be useful to identify obese girls because the methods sensitivity is high. Dencker et al., 2007[21] suggest, in a cross-sectional study of subjects aged 8-11 years, that BMI serves as a good surrogate marker for obesity in pre-pubertal children; however, significantly lower correlation existed for body fat distribution. During pre-puberty, the linear growth is less intense,[7,17,18] so the evaluation of this index do not present the bias resulting from the influence of height, which acts on BMI as covariable changeable with age.[22] However, a limitation in BMI use must be

underscored because it is not an adiposity quantitative measure but a body mass measure. That means that, in this stage, because of the accelerated height growth, an increase in BMI may be due to the increase not only of fatty tissue but also of lean body mass, especially among boys.[17,23] Another limitation of BMI involves the cutoffs that define obesity, as those are statistical derivations based on national representative samples.[8,22] Consequently, there is no consensus among the anthropometric criteria.[24] Thus, BMI should be used more as an obesity screening method in population studies than to identify body composition.[24]

BIA-FF presented a good correlation with BIA-T, being the best method to evaluate teenage girls in pubertal and post-pubertal stage. In that period, girls accumulate fatty tissue more rapidly and in a higher proportion than boys, reaching an annual average gain of 1.14 kg of fatty tissue, whereas boys keep a relatively constant average.[17] Unlike in boys, the growth speed is more stable in girls, and the height increase is progressively smaller.[7,17,18] Changes in body fat distribution also occur in that stage, resulting in typical android and gynecoid standard observed among girls.[17] BIA-FF also showed to be a suitable method to assess boys in pre-pubertal stage. The use of BIA-FF in that phase was evaluated by Goldfield et al., 2006,[25] who verified that the body fat percentage assessment by the bipolar balance is valid among children between 7 and 12 years of age. However, BIA-FF use in body composition assessment in overweight and obese subjects is not recommended because of an interindividual variability in fat mass estimates.[26]

ST assesses the subcutaneous body fat, and its use in children and teenagers is recommended by several

studies.[27] Prediction equations are used to determine the body fat percentage; however, it is especially valid for the population for which it is derived.[7] In this study, the fat percentage obtained by skinfold, especially when obtained by Deurenberg predictive equation, was capable of predicting adiposity among truly obese boys in post-pubertal stage. Otherwise, Rodriguez et al, 2005[28] showed that limits of agreement were narrower in other equations than those obtained from the Deurenberg predictive equation. In that stage, boys have a significant increase in bone and muscle growth with a simultaneous loss of fat in the limbs,[7,17] and the presence of subcutaneous fatty tissue may be an obesity indicator among boys, which may not have been detected by the other methods. According to Nooyens et al, 2007,[27] the skinfold method presented the best capacity of predicting obesity in adulthood, when compared with BMI.

WC is an important abdominal obesity indicator among children and teenagers, being able to predict the future risk of metabolic complications.[29] In this study, WC presented highest specificity in the adiposity assessment in pre-pubertal stage in boys and pubertal stage in both gender. This adiposity assessment is, probably, more abdominal adiposity than general adiposity. The cut-ffs found are above the 75 percentile proposed by Fernández et al., 2004,[30] which facilitate its use in population screening. According to those authors, WC values that are higher than the 75 and 90th are important to identify comorbidities, such as heart diseases, hyperinsulinaemia and diabetes mellitus. The definition of accurate parameters that predict abdominal adiposity risk in children and teenagers through the WC is scarce and restricted to specific population studies[9,30,31] perhaps because individuals are under full body development or because of the lack of internationally determined prospective studies that prove the association of WC cutoffs to the risk of diseases.

The graphical analysis of several cutoffs obtained by different methods allowed us to choose the most suitable for screening study, that is, with highest sensitivity (BMI), but, for being less precise, it must be associated with the most specific method to confirm obesity (BIA-FF). This procedure's association combines the low cost and practicality of BMI with the precision obtained by BIA-FF. As expected, the cutoffs verified in this study differ from the cutoffs from other studies analyzing body fat because body standard varies according to the ethnic group.[9,19,31] The body fat cutoff values of 20% for boys and 30% for girls, defined by Williams et al, 1992,[32] show the inconvenience to be for race-defined population (black and white) and maybe inappropriate for mixed-race population. In accordance to Eissa et al., 2009,[20] BMI, fat-free mass index, fat mass index, and WC change during adolescence and diverge between black and white girls and boys. In spite of study in Ouro Preto does not to define cutoffs, demonstrate the need to carry out studies wider in mixed race populations to determine these anthropometric parameters.[33]

In evaluating all the values for BMI, WC, body fat percentage by skinfold thickness, and bipolar impedance, it was observed that these are below the 85th risk indicator, which makes the nutritional evaluation by sexual maturity stage and ethnic group more sensible.[34]

A limitation of this study was that the age group analyzed in our study was up to 15 years, when puberty development usually occurs on later in boys than in girls.[7,17,18] This fact may have interfered in the low number of boys in pre-pubertal stage. Another limitation of this study was the use of the self-referred sexual maturity. However, some authors showed good agreement between child and physician assessment of sexual maturity status.[35]

Conclusion

In this study good correlation between BIA-T and BMI, WC, and BIA-FF methods was observed, especially in girls. The results suggest that BIA-FF and BMI are choice methods for obesity screening in mixed population and that the method choice for body fat screening must be done according to sexual maturity of boys and girls. The present study demonstrates the need to perform studies in wider mixed-race population to determine anthropometric parameters and to examine the predictive ability of methods and cutoffs here elucidated in the development of obesity.

Acknowledgments

Key points

This study shows that BMI and body fat assessment through bipolar impedance was the most accurate method to identify children and teenagers in risk of obesity in comparison with reference method.

The cutoffs for each method increased according to gender and sexual maturity, showing the interference of hormonal changes in body composition during puberty, and that cutoffs should be defined by sexual maturity.

Implications for public health policy and practice are the larger number of tools for the analysis of the corporal profile, especially in childhood and adolescence, will enable preventive actions that are more effective in the obesity reduction.

References

1. Botton J, Heud B, Ketteneh A et al. Cardiovascular risk factor levels and their relationships with overweight and fat distribution in children: The Fleurbaix Laventie Ville Sante' II study. *Metabolism* 2007; 56: 614-22.
2. WHO. Population-based prevention strategies for childhood obesity: report of a WHO forum and technical meeting, Geneva, 15-17 December 2009. Available at: http://www.who. int/diet-physicalactivity/childhood/child-obesity-eng.pdf. (Accessed in July 2011).
3. IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa de Orçamentos Familiares 2008-2009: Antropometria e estado nutricional de crianças, adolescentes e adultos no Brasil. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística. Available at: <http://www.ibge.gov.br/home/estatistica/popula-cao/condicaodevida/pof/2008_2009_encaa/pof_20082009_encaa.pdf>. (Acessed in June 2011).
4. Weiss R, Kaufman FR. Metabolic complications of childhood obesity: Identifying and mitigating the risk. *Diabetes Care* 2008; 31 (Suppl. 2): S310-S316.
5. Nathan BM, Moran A. Metabolic complications of obesity in childhood and adolescence: more than just diabetes. *Curr Opin Endocrinol* Diabetes *Obes* 2008; 15: 21-29.
6. Li M, Li S, Baur LA, Huxley RR. A systematic review of school-based intervention studies for the prevention or reduction of excess weight among Chinese children and adolescents. *Obes Rev* 2008; 9 (6): 548-559.
7. Siervogel RM, Demerath EW, Schubert C et al. Puberty and body composition. *Horm Res* 2003; 60: 36-45.
8. Freedman DS, Ogden CL, Berenson GS, Horlick M. Body mass index and body fatness in childhood. *Curr Opin Clin Nutr Metab Care* 2005; 8: 618-23.
9. Hatipoglu N, Ozturk A, Mazicioglu MM et al. Waist circumference percentiles for 7- to 17-year-old Turkish children and adolescents *Eur J Pediatr* 2007; 167 (4): 383-9.
10. INEP. Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira. Matrícula no ensino fundamental no município de Ouro Preto, Minas Gerais 2006. Available at: http://www.edudatabrasil.inep.gov.br/index.htm. (Accessed in September 2007).
11. Abrantes MM, Lamounier JA, Colosimo EA. Prevalência de sobrepeso e obesidade nas regiões Nordeste e Sudeste do Brasil. *Rev Assoc Med Bras* 2003; 49: 162-6.
12. Onis M et al. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007; 85: 660-7.
13. Deurenberg P, Pietersa JJL, Hautvasta JGAJ. The assessment of the body fat percentage by skinfold thickness measurements in childhood and young adolescence. *Br J Nutr* 1990; 63: 293-303.
14. Slaughter MH, Lohman TG, Boileau RA et al. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60: 709-23.
15. Tanner JM. Growth at adolescence, 2nd Ed. Oxford: Blackwell Scientific Publications 1962; p. 326.
16. Lazzer S, Boirie Y, Meyer M, Vermorel M. Which alternative method to dual-energy X-ray absorptiometry for assessing body composition in overweight and obese adolescents? *Arch Pediatr* 2005; 12: 1094-101.
17. Rogol AD, Roemmich JN, Clark PA. Growth at puberty. *J Adolesc Health* 2002; 31 (6 Suppl.): 192-200.
18. Veldhuis JD, Roemmich JN, Richmond EJ. et al. Endocrine control of body composition in infancy, childhood, and puberty. *Endocr Rev* 2005; 26: 114-46.
19. Díaz E, Burrows R, Muzzo S, Galgani J, Rodríguez R. Evaluación nutricional de adolescentes mediante índice de masa corporal para etapa puberal. *Rev Chil Pediatr* 1996; 67 (4): 153-58.
20. Eissa MA, Dai S, Mihalopoulos NL, Day RS, Harrist RB, Labarthe DR. Trajectories of fat mass index, fat free–mass index, and waist circumference in children. Project HeartBeat! *Am J Prev Med* 2009; 37 (1S): S34-S39.
21. Dencker M, Thorsson O, Lindén C. et al. BMI and objectively measured body fat and body fat distribution in prepubertal children. *Clin Physiol Funct Imaging* 2007; 27: 12-6.
22. Sweeting HN. Measurement and definitions of obesity in childhood and adolescence: A field guide for the uninitiated. *Nutr J* 2007; 6: 32.
23. Siervogel RM, Maynard LM, Wisemandle WA et al. Annual changes in total body fat and fat free mass in children from 8 to 18 years in relation to changes in body mass index:The Fels Longitudinal Study. *Ann N Y Acad Sci* 2000; 904: 420-3.
24. Flegal KM, Tabak CJ, Ogden CL. Overweight in children: definitions and interpretation. *Health Educ Res* 2006; 21 (6): 755-60.
25. Goldfield GS, Cloutier P, Mallory R, Prud'homme D, Parker T, Doucet E. Validity of foot-to-foot bioelectrical impedance analysis in overweight and obese children and parents. *J Sports Med Phys* Fitness 2006; 46: 447.
26. Lazzer S, Boirie Y, Meyer M, Vermorel M. Evaluation of two foot-to-foot bioelectrical impedance analysers to assess body composition in overweight and obese adolescents. *Br J Nutr* 2003; 90 (5): 987-92.
27. Nooyens AC, Koppes LL, Visscher TL et al. Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: the Amsterdam Growth and Health Longitudinal Study1-3. *Am J Clin Nutr* 2007; 85: 1533-9.
28. Rodríguez G, Moreno LA, Blay MG et al. Body fat measurement in adolescents: comparison of skinfold thickness equations with dual-energy X-ray absorptiometry. *Eur J Clin Nutr* 2005; 59: 1158-1166.
29. Plachta-Danielzik S, Landsberg B, Johannsen M, Lange D, Müller MJ. Association of different obesity indices with blood pressure and blood lipids in children and adolescents. *Br J Nutr* 2008; 100: 208-18.
30. Fernandez JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-american, European-american and Mexican-american children and adolescents. *J Pediatr* 2004; 145: 439-44.
31. Botti AB, Pérez Cueto FJA, Vasquez Monllor PA, Kolsteren YPW. Referencias antropométricas de los adolescentes bolivianos de 12 a 18 años: estatura, peso, circunferencia del brazo, muñeca, y abdominal, índice de masa corporal. Percentiles de adolescentes bolivianos (PAB) del estudio mesa. *Nutr Hosp* 2009; 24: 304-311.
32. Williams DP et al. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. *Am J Public Health* 1992; 82: 358-63.
33. Cândido APC, Benedetto R, Castro APP et al. Cardiovascular risk factors in children and adolescents living in an urban area of Southeast of Brazil: Ouro Preto Study. *Eur J Pediatrics* 2009; 168 (11): 1373-82.
34. Kuczmarski RJ, Ogden CL, Guo SS et al. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat* 2002; 246: 1-190.
35. Schall JI, Semeao EJ, Stallings VA, Zemel BS. Self-assessment of sexual maturity status in children with Crohn's disease. *J Pediatr* 2002; 141: 223-9.