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Correlation between percentage of body fat measured by the Slaughter equation and bio impedance analysis technique in Mexican schoolchildren

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Abstract

Introduction: **Obesity is considered one of the most serious public health problems of the 21st century in children and adolescents. The percentile or Z-score of the body mass index is widely used in children and adolescents to define and assess overweight and obesity, but it does not determine the percentage of total body fat. Other anthropometric measurements that determine total body fat are skinfold thickness and methods of body composition assessment such as bio impedance analysis, both of which are rapid and inexpensive.**

Objetive: **The aim of the study was to correlate the percentage of body fat determined by the Slaughter equation with the percentage of body fat determined by the bio impedance analysis technique, and the body mass index in schoolchildren.**

Methods: **The design of the study is cross-sectional and it was performed on a random selection of 74 children (9.47 ± 1.55 years old) attending a primary school in Colima, Mexico during 2011. The percentage of body fat was measured by the Slaughter equation and bio impedance analysis technique. Body mass index was calculated. Inferential statistics were performed with the non-paired Student's t test, Pearson's correlation for quantitative variables (percentage of body fat by the Slaughter equation and bio impedance analysis) and the Fisher exact test for qualitative variables.**

Results: **A significant correlation ($r = 0.74$; $p < 0.001$) was identified between the percentage of fat measured by the Slaughter equation and bio impedance analysis. We also identified a significant correlation between the percentage of fat measured by the Slaughter equation and body mass index ($r = 0.85$; $p < 0.001$) and the percentage of fat measured by bio impedance analysis and body mass index ($r = 0.78$; $p < 0.001$).**

Conclusion: **Given that we identified a significant positive correlation between BIA and STE, we conclude that both are adequate alternatives for measuring the percentage of body fat among schoolchildren in our population.**

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Key words: *Body fat. Body mass index. Skinfold thickness. Slaughter equation. Bioimpedance analysis.*

CORRELACIÓN ENTRE EL PORCENTAJE DE GRASA DETERMINADO MEDIANTE LA ECUACIÓN DE SLAUGHTER E IMPEDANCIA BIOELÉCTRICA EN NIÑOS MEXICANOS EN EDAD ESCOLAR

Resumen

Introducción: **La obesidad en el siglo XXI es considerado ya como un problema serio de salud pública, tanto en niños como adolescentes. El puntaje Z del indicador índice de masa corporal para la edad es ampliamente utilizado en el área de pediatría para definir sobrepeso y obesidad, sin embargo, dicho indicador no permite determinar el porcentaje de grasa total en el cuerpo. Existen otros métodos antropométricos que permiten determinar el porcentaje de masa grasa, como son los pliegues cutáneos o métodos que determinan la composición corporal, como es la impedancia bioeléctrica, ambos rápidos de realizar y a un bajo costo.**

Objetivo: **Correlacionar el porcentaje de grasa corporal determinado mediante la ecuación de Slaughter con el porcentaje de grasa determinado por impedancia bioeléctrica y con el indicador índice de masa corporal en niños en edad escolar.**

Material y método: **El diseño del estudio fue transversal analítico y se realizó en una muestra de 74 niños seleccionados al azar (9,47 ± 1,55 años de edad) que asisten a una escuela primaria en Colima, México en el 2011. El porcentaje de grasa se realizó con la ecuación de Slaughter, impedancia bioeléctrica y además se calculó el índice de masa corporal. El análisis estadístico inferencial se realizó con la prueba T de Student, correlación de Pearson para establecer relación entre el porcentaje de grasa determinado por la ecuación de Slaughter e impedancia bioeléctrica así como prueba exacta de Fisher para variables cualitativas.**

Resultados: **Se identificó una correlación significativa ($r = 0,74$; $p < 0,001$) entre el porcentaje de grasa determinado por la ecuación de Slaughter y la impedancia bioeléctrica. Así mismo, se identificó una correlación significativa entre el porcentaje de grasa determinado por la ecuación de Slaughter y el índice de masa corporal ($r = 0,85$; $p < 0,001$) y el porcentaje de grasa determinado por impedancia bioeléctrica y el índice de masa corporal ($r = 0,78$; $p < 0,001$).**

Conclusión: **Dada la correlación positiva y significativa del porcentaje de grasa determinado mediante la ecuación de Slaughter y la impedancia bioeléctrica, se concluye que son alternativas adecuadas para determinar el porcentaje de grasa corporal en niños escolares mexicanos.**

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Palabras clave: *Grasa corporal. Índice de masa corporal. Pliegues cutáneos. Ecuación de Slaughter. Impendancia bioeléctrica.*

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Introduction

The problem of childhood obesity is worsening at a dramatic rate worldwide.[1] The prevalence of obese children and adolescents with hyperlipidemia, hypertension, insulin resistance, and type 2 diabetes is increasing at an alarming rate.[2,3,4] In order to detect health risks as early as possible among the pediatric population, the measurement of body fat (BF) is fundamental and adiposity can be evaluated by several field and laboratory-based methods, although their complexity and high cost are important limitations.[5-9]

Anthropometry is one of the most basic tools for assessing nutritional status.[8,10] At present, body mass index (BMI), skinfold thickness (ST) measurements and bio impedance analysis (BIA) are the most commonly used methods because they can be performed relatively quickly and inexpensively.[4,7,11] BMI [weight (kg)/height^2(m)] is widely used to define and assess overweight and obesity, but it does not determine the percentage of the total BF.[9-15] ST and BIA require equations to calculate BF percentage, but compared with other methods, they are easy to use in large field studies.[7] Different equations for estimating ST in children correlate reasonably well with body fatness,[8,12] although ethnic-related differences in the ability to accurately predict BF have been reported.[7,10,16] BIA is an attractive method for estimating body composition in children,[17] although whether it is an appropriate alternative to dual-energy x-ray absorptiometry (DXA) remains controversial.[18-24]

The purpose of this study was to correlate the percentage of BF determined by the Slaughter equation (STE), with the percentage of body fat determined by BIA and the BMI in schoolchildren.

BIA, and BMI in primary school children.

Methods and materials

Protocol

Design: Cross-sectional. *Inclusion and setting*: The study was performed on children attending a primary school in Colima, Mexico during 2011. *Sampling*: The population was comprised of 74 randomly selected school children. *Variables*: Percentage of body fat measured by the STE, BIA, and BMI. Malnourished children according to BMI Z-score were excluded.

Anthropometric and body composition assessments

All measurements were carried out in the school settings by trained technicians. For weight and height measurement a digital scale (Ironman brand TANITA BC-558 Inner Scan/Segmental) and a portable stadiometer (Tanita brand HR-200, length 64-214 cm) were used, respectively, and assessments were done with children in light clothing, without shoes, and according to standard procedures.[25] BMI was calculated as weight (kg) divided by height squared (m^2). Definitions of thinness, overweight, and obesity among children were based on the WHO Z scores of BMI for age. Standard deviations under -2 for thinness, above +1 for overweight, and above +2 for obesity were used.[26,27] Children's triceps and subscapular ST were measured to the nearest 1 mm with a Lange skinfold caliper; both measurements were made on the right side of the body. The triceps skinfold site was located as the middle point on the posterior side of the arm, between the acromion and olecranon above the triceps, and then marked. The technicians performing the measurement used their left hand to pinch the subcutaneous fat 1 cm above the mark. The skinfold caliper was applied horizontally on the mark, maintaining the pinch with the left hand, for about three seconds. The subscapular ST was obtained by pinching the inner edge of the shoulder blade at an angle of 45°. Both of the skinfold sites were located with the subjects in a relaxed standing position with their arms hanging by their sides and the measurements were made three times,[25] obtaining the mean to use for the analysis. The following equation was used to estimate body fat percentage:

Slaughter et al.[7,10]

Girls	%BF = 1.33 (Tri + Sub) - 0.013 (Tri + Sub)^2- 2.5
Boys	%BF = 1.21 (Tri + Sub) - 0.008 (Tri + Sub)^2 – 1.7

%BF = Percent body fat; Tri = Tricipital skinfold; Sub = Subscapular skinfold.

Whole body impedance at 50 kHz was measured using the Quadscan 4000 analyzer (Bodystat Limited, Great Britain). An eight-hour fast and an empty bladder were required for the analysis. Clothes were allowed, except for shoes and socks, and metal objects were removed (watches, chains, earrings, etc). Children were placed supine on a surface at room temperature, with arms slightly away from the body and legs apart. Subsequently, two electrodes were placed on the back of the hand (at the wrist and metacarpal) and two on the back foot (tarsus and ankle). The red lead was connected to the distal electrode and the black lead to the proximal. Age, height, weight, waist and hip measurements, and physical activity level data were first introduced into the device, it was turned on to allow the passage of electric current through the body, and then its predictive equation results were displayed. The percentage of BF determined by the STE and BIA was classified according to the McCarthy et al. children's sex-specific centile curves of BF references as underfat (UF), normal weight (NW), overfat (OF) and obese (OB), set at the 2nd, 85th and 95th centiles.[14]

Statistical analysis

The data was analyzed with the SPSS version 20 program. The variables studied were described as

Table I
Anthropometric characteristics and body fat percentage for schoolchildren of both sexes. Data are reported as mean ± standard deviation

Variables	*Girls (mean ± SD)*	*Boys (mean ± SD)*	*p**
Weight (kg)	39.59 ± 13.89	40.15 ± 15.70	0.873
Height (m)	1.38 ± 0.12	1.38 ± 0.12	0.965
BMI (kg/m^2)[a]	20.13 ± 4.15	20.35 ± 5.17	0.838
Z score BMI	1.10 ± 1.33	1.11 ± 1.71	0.983
Triceps SF (mm)[b]	18.68 ± 5.46	17.93 ± 7.55	0.637
Subscapular SF(mm)[c]	19.02 ± 7.88	17.64 ± 9.96	0.520
BF-STE- (%)[d]	27.07 ± 5.22	28.97 ± 10.13	0.331
BF-BIA (%)[e]	28.88 ± 8.61	24.77 ± 9.11	0.052

[a]Body mass index.
[b]Tricipital skinfold thickness.
[c]Subscapular skinfold thickness.
[d]Body fat by skinfold thickness in accordance with Slaughter et al.
[e]Body fat by the bioelectrical impedance technique.
*Calculated with the Student's t test.

frequencies and percentages or as means and SD; inferential statistics were performed with the non-paired Student's *t* test and Pearson's correlation for quantitative variables and the Fisher exact test for qualitative variables. Statistical significance was set at a p value < 0.05.

Ethics

Informed consent was obtained from the parents or guardians. The study's protocol was approved by the Ethics Committee of the University of Colima, (# 07/2012) which conforms to the guidelines of the Declaration of Helsinki, and in regard to the principles of beneficence, non-maleficence, justice, and autonomy of decision. (Ethical Principles for Medical Research Involving Human Subjects. 52nd release, October 2000).

Results

The sample of 74 schoolchildren was composed of 55.4% boys (n = 41) aged 9.4 ± 1.5 years old and 44.6% girls (n = 33) aged 9.4 ± 1.6 years old. The anthropometric characteristics of the children and body fat percentage measured with BIA and STE are shown in table I. No statistical differences were observed between girls and boys, and the BF% measured by BIA in girls was almost significantly higher when compared with boys.

A comparison of the nutritional diagnosis obtained by BF% with the STE and BIA is shown in table II. BF% measured with BIA shows 8% of the children diagnosed as UF, even though at the beginning of the study the children that had a BMI Z-score < -2 SD were excluded. The comparison of the frequency of NW, OF and OB was similar between the two methods (p > 0.05).

Table II
Comparison of the frequency of percentage of fat according to the McCarthy classification, using the STE and BIA

Nutritional diagnosis	*BF%-STE (Slaughter equation)*[7]		*BF%-BIA (McCarthy et al.)*[8]	
	n	*%*	*n*	*%*
UF[a]	0	0%	6	8.1%
N[b]	27	36.5%	27	36.5%
OF[c]	20	27.0%	13	17.6%
OB[d]	27	36.5%	28	37.8%

[a]Under fat.
[b]Normal weight.
[c]Overfat.
[d]Obese.
BF% BIA *vs.* BF% ST (p = 0.116).
The p values were calculated with the Fisher test.

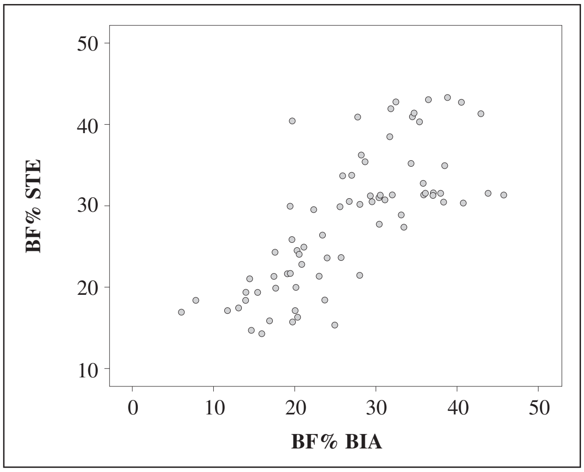

Fig. 1.—Correlation between BF% with STE and BIA (r = 0.74, p < 0.001).

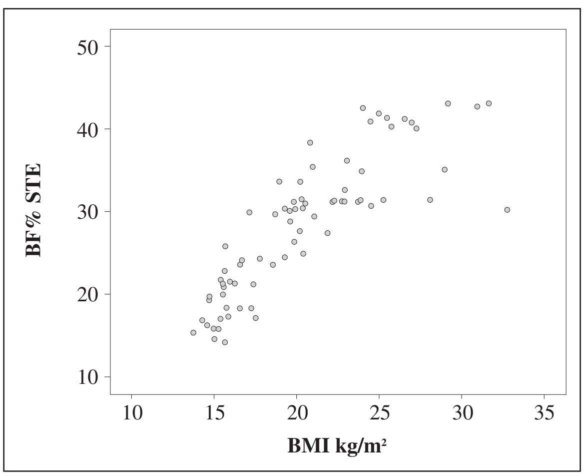

Fig. 2.—Correlation between BF%-STE and BMI (r = 0.85, p < 0.001).

In this study both BIA and STE proved to be adequate techniques for measuring BF% in children, since a significant correlation ($r = 0.74$, $p < 0.001$) between these two methods was identified (fig. 1).

We also observed a significant correlation between BF%-STE and BMI ($r = 0.85$, $p < 0.001$) (fig. 2), and BF%-BIA and BMI ($r = 0.78$, $p < 0.001$) (fig. 3).

Discussion

In the present study, the STE and BIA were shown to be adequate techniques for measuring BF% in our population of schoolchildren, since the correlation between these two methods together with BMI was strong. Correlation with BMI is important because BMI for age, together with percentile cut-off interpretations or BMI Z-score, has been recommended as the method of choice for diagnosing overweight and obesity in children and adolescents by several evidence-based guidelines and expert committees, and

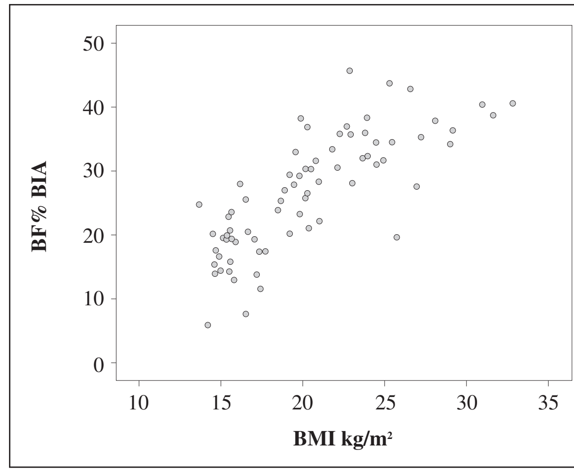

Fig. 3.—Correlation between BF%-BIA and BMI (r = 0.78, p < 0.001).

is well established for both clinical and public health applications.[5,28] Some analyses have indicated that BMI levels in children are strongly correlated with various cardiovascular disease risk factors, as is the sum of tricipital and subscapular ST.[9]

A variety of methods are available to measure BF; these techniques include DXA, underwater weighing, total body water, and computed tomography, but they have limited use due to their complexity and high cost. Several studies have compared different inexpensive and replicable methods for measuring adiposity in children in order to establish a correct nutritional diagnosis and their results were similar to those of our study.[5,12,29,30] In a cohort of 228 6-year-old Italian children, fat mass was evaluated using triceps ST and BIA and identified a strong correlation between BIA and BMI ($r = 0.92$; $p < 0.001$) and between BIA and triceps ST ($r = 0.79$; $p = 0.001$). The authors concluded that BIA is a more useful alternative method than triceps ST for assessing body composition in children.[11] A Brazilian study performed on 788 schoolchildren aged 6-15 years found a good correlation between BIA and BMI ($r = 0.87$; $p = 0.01$) and WC ($r = 0.84$; $p = 0.01$), especially in girls, and suggested that both methods are adequate choices for body fat screening.[3] A Polish study also compared accuracy between BIA and BMI for fat mass evaluation in 193 children aged 11.8 ± 2.2 years. They compared percentile charts of fat mass and BMI and found different shapes of fat mass content and BMI curves for boys during puberty, but concluded that BIA is accurate for evaluating fat mass content in children and that it should be widely used.[32]

ST performed on children also seems to be a valid option for establishing a nutritional diagnosis when compared with DXA[12,31] and BIA;[11,33] however, ST measurements may not provide additional information about excess body fat beyond BMI for age alone if the BMI for age is > 95th percentile.[15] BMI from a sample of 2600 Swiss children aged 6-12 years old was well correlated with the BF% from multisite ST for identifying overweight (r = 0.74). According to the study, BF% values calculated from ST have high reproducibility and correlate well with BF% values measured with DXA in children.[12] In a study performed in the United States, 98 children aged 6.6 ± 1.4 years old were measured with DXA as a standard method for determining body composition, ST with the Slaughter et al. equations, bioelectrical resistance, and BMI for the assessment of BF. FM measured by DXA was strongly correlated with FM measured by ST (r = 0.87), FM measured by BR (r = 0.76), and other anthropometric and skinfold-thickness measures (r = 0.64-0.83).[31] In Poland, a study on 324 children aged 7-18 years reported a significant correlation between the BF% by BIA and ST using the STE, as well.[33]

Despite being easily reproducible techniques, the main limitations with anthropometry and BIA are the need for specific calibration equations that may not always accurately predict body fat in certain populations because they are more sensitive to the ethnicity of the population they were made for.[34,35.] BIA results are unreliable when the equation is not appropriately chosen based on age, sex, level of physical activity, level of body fat, and ethnicity.[36] A study performed in India in which the authors tried to assess agreement between the BF% derived from DXA and from skinfold equations and BIA, reported that the STE tended to underestimate BF% for the vast majority of Indian children.[4]

In other respects, we classified the percentage of body fat as UF, NW, overfat (OF), and obese, according to the McCarthy children's body fat curves, with no significant difference in obesity frequency when comparing the BF% assessed by the STE and BIA. We are aware that the McCarthy charts were performed on Caucasian children, but despite this fact we used these curves in our study because there are no existing children's body fat curves for Latino children to compare our results with.[14]

It is important to mention that BIA was the only method that identified underweight children. Some authors have reported that BIA seems to be a reasonable method for daily clinical use, but attention should be paid to the interpretation of the percentage of fat values in underweight and overweight children.[37]

Conclusion

Given that we identified a significant positive correlation between BIA and STE, as well as with the BMI, we conclude that these two BF% measurement techniques are adequate alternatives for measuring adiposity among the children in our population.

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