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Trabajo Original

Pediatría

Estimation of body fat among 2-to-7-year-old Spanish children by different skinfolds equations and waist-to-height ratio

Determinación de grasa corporal en niños españoles de 2 a 7 años mediante diferentes fórmulas de plicometría y el índice cintura-talla

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Abstract

Introduction: It seems relevant to analyze the body composition in the early childhood. However, there is not an agreement in the protocol to assess body composition in this age range/group.

Objective: To determine the most useful equation to estimate the body fat percentage that preschool children contain and the utility of the waist-to-height ratio to determine abdominal obesity.

Methods: We measured (weight, height, waist circumference and skinfolds) in 285 children aged 2 to 7 years old. BMI Z-Score, waist-to-height ratio and body fat percentage were estimated by Brook and Lukaski, Siri, Goran, Slaughter, Deurenberg, Huang, Dezenberg and Hoffman equations.

Results: It was found 26% combined overweight and obesity, with similar distribution in both sexes. The body fat obtained with the Hoffman equation (15.6-31.9%) showed the highest correlation with children BMI Z-Score. Waist-to-height ratio also presented a good relationship with children weight status. There were not significant differences between gender and body fat percentage or waist-to-height ratio.

Conclusions: Hoffman equation and waist-to-height ratio could be adequate to estimate body fat percentage and abdominal obesity respectively in Spanish preschool children from medium-low socioeconomic status.

Key words:

Preschool child.
Abdominal obesity.
Body composition.
Anthropometry.

Resumen

Introducción: parece relevante analizar la composición corporal en la primera infancia. Sin embargo, en este rango de edad no existe un protocolo consensuado para determinar la composición corporal.

Objetivo: determinar la fórmula más útil para estimar el porcentaje de grasa corporal contenido en niños preescolares y la utilidad del índice cintura-talla para determinar la obesidad abdominal.

Métodos: medimos (peso, talla, circunferencia abdominal y pliegues cutáneos) a 285 niños de 2 a 7 años. Se estimaron el Z-Score de IMC, el índice cintura-talla y el porcentaje de grasa corporal mediante las fórmulas de Brook y Lukaski, Siri, Goran, Slaughter, Deurenberg, Huang, Dezenberg y Hoffman.

Resultados: se halló un 26% de prevalencia combinada de sobrepeso y obesidad, con distribución similar entre sexos. El porcentaje de grasa corporal obtenido con la fórmula de Hoffman (15,6-31,9%) mostró la mayor correlación con el Z-Score del IMC. El índice cintura-talla también presentó una buena relación con el estado nutricional de los niños. No hubo diferencias significativas entre el sexo y el porcentaje de grasa corporal o el índice cintura-talla.

Conclusiones: la fórmula de Hoffman y el índice cintura-talla podrían ser adecuados para estimar el porcentaje de grasa corporal y la obesidad abdominal respectivamente, en preescolares españoles de nivel socioeconómico medio-bajo.

Palabras clave:

Preescolar. Obesidad abdominal.
Composición corporal.
Antropometría.

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INTRODUCTION

There is great concern about overweight and obesity due to increased prevalence of these conditions in recent years, both in adults (1,2) and in children (3,4). Due to the many adverse long term effects of obesity, it has become a major focus of health care intervention and expenditure. These effects include higher risk for type 2 diabetes, degenerative joint disease, obstructive sleep apnea, hypertension, and early death in adulthood as well as hyperlipidemia and hyperglycemia in childhood (5), or metabolic syndrome in preschool children (6). Because of that, obesity is the aim of many studies around the world (7,8). Three specific periods in early life are hypothesized to be critical for the development of obesity: the perinatal period, the adiposity rebound, and adolescence. The adiposity rebound is the point at which the BMI (body mass index) reaches a nadir and then begins to increase, it occurs around 6 and it is related with parents' BMI (9).

It seems relevant to analyze the body composition in the early childhood (8,10). Childhood obesity studies usually include very broad age ranges (11) and mostly focus on more than 8-year-old children or teenagers (12). However, younger ages are less studied (13-16), especially in Spain.

To diagnose obesity, BMI and body composition are used. The latter parameter can be measured by several methods that vary in their sophistication, accuracy, feasibility, cost, and availability. In small children, magnetic resonance imaging and DEXA have cost, ethical and time consuming limitations and bio-electrical impedance analysis (BIA) has an availability limitation (not accessible to children smaller than 5 years old), despite being the most reliable methods (16-19). On the other hand, air displacement plethysmography does not seem to be appropriate in early childhood (17). Nevertheless, anthropometry by skinfolds offers a good accessibility, low cost and an acceptable accuracy (20).

A large number of studies determine body composition by several equations to estimate the body fat percentage from skinfolds, however most of them have been executed in school children or teenagers (21-23), in preschool children it has been considerate by other authors (24-26). On the other hand, BMI should be used regarding age and sex (26,27).

The aim of this paper is to determine previously published equation to estimate the body fat percentage in early childhood, as a more accessible, quicker, cheaper and non-aggressive method, that has the higher correlation with weight status by BMI Z-Score. As well as analyze the utility of waist-to-height ratio to determine the abdominal obesity in Spanish preschool children.

MATERIALS AND METHODS

DESIGN

A descriptive study with quantitative analysis was executed with children aged 2 to 7 years old from Rafal, a population of Alicante (Spain).

PARTICIPANTS

Two hundred and eighty-five children were included in the study, 146 (51.2%) girls median age 5.0 (SD 1.5) years and 139 (49.8%) boys of 5.1 (SD 1.4) years old. They are 72.3% of total children in the municipality from this age range. These children were from the unique school and the only two kindergartens of this municipality. Socioeconomic status of the families was medium-low and the rate of children with immigrant parents was 22.5%, mostly of Moroccan origin, according to census data.

The inclusion criteria were: 2- to 7-year-old children; whose parents had been informed about the nature of the study and had read and signed informed consent. As exclusion criteria: children under 2-years-old or over 7-years-old, children with Down syndrome and every child whose parents did not sign informed consent to participate in this study.

ENVIRONMENT

Anthropometry was executed in the school multipurpose classroom and in the pediatric clinic medical office population.

TOOLS

Auxological parameters were measured by two trained nutritionists. Seca weighing-scales (761 Clas IIII, accuracy 0.5 kg), a harpenden stadiometer (Holtain Limited, Crymch, Dyfed U.K.), which determines height accurately within 0.1 cm and two Holtain skinfolds calipers (Holtain Limited, Crymch, Dyfed U.K.) which determines skinfolds accurately within 0.1 mm. Weight, stature, abdominal circumference and biceps, triceps, subscapular and suprailiac skinfolds were measured.

PROCESS

The study protocol was approved by the ethics committee of the Universidad de Alicante before its initiation.

For the anthropometry study, nutritionists addressed children to the multipurpose classroom in small groups of 4 children. They were observed while drawing or playing with toys to determine the most used arm. When it was detected, researchers helped children take off their shoes and their outer clothing and then they measured weight, stature and triplicate measure waist and skinfold listed above in every child. Parents were present, if they wanted, with their children during the measurement process.

BMI (kg/m^2) was calculated from parameters obtained and BMI Z-Score was calculated in relation to their age and gender by Seinaptraker program (28), based on Orbegoza Foundation standards 1988. Children were classified by BMI Z-Score in 4 subgroups: thinness $Z_s \leq -1$, normal weight $Z_s -0.99-0.99$, overweight $Z_s \geq 1$ and obesity $Z_s \geq 2$.

Waist-to-height ratio and the body fat percentage were also calculated with the assistance of SPSS Statistics (24.0). The last parameter was estimated using skinfolds with different equations designed to estimate body fat mass:

- *Brook y Lukaski (29)*:
 - Boys $D = [1.1315 + 0.0018 (\text{age}-2)] - [0.0719 - (0.0006 (\text{age}-2) * \log (\Sigma \text{biceps} + \text{triceps} + \text{subscapular} + \text{suprailiac})]$.
 - Girls $D = [1.1315 + 0.0004 (\text{age}-2)] - [0.0719 - (0.0003 (\text{age}-2) * \log (\Sigma \text{bicipital} + \text{tricipital} + \text{subscapular} + \text{suprailiac})]$. (D = density).
- *Siri (29)*:
 - Boys $D = 1.1690 - 0.0788 * \log (\Sigma \text{biceps} + \text{triceps} + \text{subscapular} + \text{suprailiac})$.
 - Girls $D = 1.2063 - 0.0999 * \log (\Sigma \text{biceps} + \text{triceps} + \text{subscapular} + \text{suprailiac})$. (D = density). $\%BF = (4.95/D - 4.5) \times 100$.
- *Goran (30)*:
 - $\%BF = \text{weight} * (0.18 * \text{weight} + 0.23 * \text{subscapular} + 0.13 * \text{triceps} - 3.0) / 100$.
- *Slaughter (31)*:
 - Boys $\%BF = \text{weight} * [(1.21 * (\text{triceps} + \text{subscapular}) - 0.008 (\text{triceps} + \text{subscapular})^2 - 1.7) / 100]$.
 - Girls $\%BF = \text{weight} * [1.33 * (\text{triceps} + \text{subscapular}) - 0.013 (\text{triceps} + \text{subscapular})^2 - 2.5] / 100$.
- *Deurenberg (32)*:
 - Boys $\%BF = \text{weight} * [26.56 (\log \Sigma \text{biceps} + \text{triceps} + \text{subscapular} + \text{suprailiac}) - 22.23] / 100$.
 - Girls $\%BF = \text{weight} * [29.85 (\log \Sigma \text{biceps} + \text{triceps} + \text{subscapular} + \text{suprailiac}) - 25.87] / 100$.
- *Huang 1 (33)*:
 - $\%BF = \text{weight} * (0.632 * \text{weight} - 1.606 * \text{age} - 1.882 * \text{gender} + 3.33) / 100$ (gender 0 = girls; 1 = boys; age in years).
- *Huang 2 (33)*:
 - $\%BF = \text{weight} * (0.764 * \text{weight} - 0.471 * \text{stature} + 45.955) / 100$ (stature in cm).
- *Dezenberg 1 (34)*:
 - $\%BF = \text{weight} * (0.342 * \text{weight} + 0.256 * \text{triceps} + 0.837 * \text{gender} - 7.388) / 100$ (gender 1 = boys; 2 = girls).
- *Dezenberg 2 (34)*:
 - $\%BF = \text{weight} * (0.332 * \text{weight} + 0.263 * \text{triceps} + 0.760 * \text{gender} + 0.704 - 8.004) / 100$ (gender 1 = boys; 2 = girls).

– *Hoffman (22)*:

- $\%BF = 100 [6.371 + 0.488 * \text{weight} + 0.128 * \text{triceps} (11.138 * \text{stature} + 0.645 * \text{gender} - 0.188 * \text{age}) / \text{weight} (\text{stature in cm; gender } 0 = \text{boys; } 1 = \text{girls; age in years})]$.

STATISTICAL ANALYSIS

To determine if there are significant differences in the children distribution according to weight status a Chi-squared test was executed. To determine the equation that has a better correlation with children weight status, regression lineal study between the estimated body fat percentage from each equation and BMI Z-Score in both genders was effected. The same test was completed for waist-to-height ratio. Finally, to verify the effectiveness of each of the equations used comparison statistical study of body fat percentages obtained according to weight status was performed, using the nonparametric U Mann-Whitney test. Significance at $p < 0.05$ was considered.

RESULTS

Gender distribution was similar in all weight status groups, without significant differences by Chi-squared test. Combined overweight and obesity prevalence was 26% (Table I).

Body fat percentages obtained with Hoffman equation showed the highest correlation with children weight state according to BMI Z-Score ($p < 0.001$). Other equations also obtained significant differences between weight status and body fat percentage to both genders ($p < 0.001$), except for Brook and Lukaski and the second Huang equations which did not present significant correlation to weight status (Table II). Waist-to-height ratio presented a good level of correlation versus BMI Z-Score as well, 0.643 in boys and 0.683 in girls, with a high signification level ($p < 0.001$) (Table II). In all cases, a slightly better correlation coefficient (r^2) in girls was shown.

Average, standard deviation and confidence interval 95% values to body fat percentage obtained by every equation are shown in table III, which is observed as with the correlation level that Brook and Lukaski and the second Huang equations do not present significant differences between body fat percentage and weight status by Z-Score BMI. Values that seemed undervalued

Table I. Children weight status according to BMI Z-Score

Children distribution according to gender and weight status						
		Thinness	Normal weight	Overweight	Obesity	Total
Gender	Boys	20 (14.4%)	85 (61.2%)	19 (13.7%)	15 (10.8%)	139
	Girls	22 (15.1%)	84 (57.5%)	24 (16.4%)	16 (11.0%)	146
Total		42 (14.7%)	169 (59.3%)	43 (15.1%)	31 (10.9%)	285

*No significant Chi-squared test.

Table II. Relationship between body fat percentage, by different equations or ratios, and BMI Z-Score respect age and gender in 2-to-7-year-old children

Equation/ratio	Gender	Adjusted r^2	Anova
Hoffman	Boys	0.789	0.000
	Girls	0.772	0.000
Siri	Boys	0.520	0.000
	Girls	0.578	0.000
Slaughter	Boys	0.507	0.000
	Girls	0.571	0.000
Goran	Boys	0.449	0.000
	Girls	0.562	0.000
Deurenberg	Boys	0.519	0.000
	Girls	0.574	0.000
Dezenberg 1	Boys	0.391	0.000
	Girls	0.418	0.000
Dezenberg 2	Boys	0.393	0.000
	Girls	0.419	0.000
Huang 1	Boys	0.244	0.000
	Girls	0.118	0.000
Huang 2	Boys	0.013	0.096
	Girls	-0.005	0.562
Brook y Lukaski	Boys	-0.002	0.386
	Girls	0.001	0.296
Waist-to-height ratio	Boys	0.643	0.000
	Girls	0.683	0.000

in the two Dezenberg equations with percentages ranging from 4.9% to 29.0% fat were observed, and there were overestimated values with the first Huang equation with body fat percentages from 26.8 to 44.3%.

When the values of body fat percentage in each weight group were studied, distributions were different and highly significant ($p < 0.001$) according to the equation with the best correlation coefficient, Hoffman equation was observed (Fig. 1). In this figure, body fat percentages values were always higher in girls, although these percentages were not significantly different from the same groups of weight.

Regarding to waist-to-height ratio (Fig. 2), a different distribution by weight status was shown ($p < 0.001$) (Test U de Mann-Whitney), this ratio increased with weight groups, but the difference between genders referred to the body fat percentage was not evidenced.

DISCUSSION

The equation that presents the higher correlation with BMI Z-Score in 2-to-7-year-old Spanish children is the Hoffman equation. Also, waist-to-height ratio has a high correlation level with BMI Z-Score, consequently it could be effective to determine the abdominal obesity level. It has been shown that there is a clear relationship between both parameters in all groups of weight status, the higher BMI Z-Score higher body fat percentage has the child and highest is this accumulation in the abdominal area. There are not differences between genders because of the lack

Table III. Body fat percentage estimated by different equations for every nutritional state group -average (SD) CI 95%

Equation	Thinness	Normal weight	Overweight	Obesity	U Mann-Whitney
Hoffman	16.0 (4.4)	21.2 (3.5)	26.7 (2.5)	30.8 (3.0)	< 0.001
	15.6-17.3	20.7-21.8	25.9-27.4	29.7-31.9	
Siri	14.3 (3.5)	17.6 (3.9)	22.7 (4.6)	29.5 (5.6)	< 0.001
	13.2-15.3	17.0-18.2	21.3-24.1	27.4-31.6	
Slaughter	12.6 (2.8)	15.3 (3.3)	19.4 (4.6)	26.4 (6.6)	< 0.001
	11.7-13.5	14.8-15.8	18.0-20.8	24.0-28.9	
Goran	13.2 (3.3)	16.2 (3.3)	20.3 (4.7)	26.0 (5.6)	< 0.001
	12.2-14.2	15.7-16.7	18.9-21.8	23.9-28.1	
Deurenberg	14.3 (2.7)	16.6 (3.0)	20.3 (4.0)	25.0 (4.1)	< 0.001
	13.5-15.1	16.2-17.1	19.1-21.6	23.4-26.5	
Dezenberg 1	7.8 (6.7)	13.5 (6.6)	18.4 (8.2)	26.4 (7.0)	< 0.001
	5.7-9.9	12.5-14.5	15.9-20.9	23.8-29.0	
Dezenberg 2	7.0 (6.6)	12.7 (6.6)	17.7 (8.1)	25.7 (7.0)	< 0.001
	4.9-9.0	11.7-13.6	15.2-20.1	23.1-28.3	
Huang 1	30.7 (12.6)	34.0 (10.4)	39.9 (5.1)	42.5 (5.0)	< 0.001
	26.8-34.7	32.4-35.6	38.4-41.5	40.6-44.3	
Huang 2	46.3 (24.7)	49.9 (20.6)	56.5 (21.8)	48.5 (13.7)	ns
	38.6-54.0	46.8-53.1	49.8-63.2	43.5-53.5	
Brook y Lukaski	15.0 (1.6)	14.8 (1.8)	15.4 (1.3)	14.4 (2.2)	ns
	14.5-15.5	14.5-15.1	14.9-15.8	13.6-15.2	

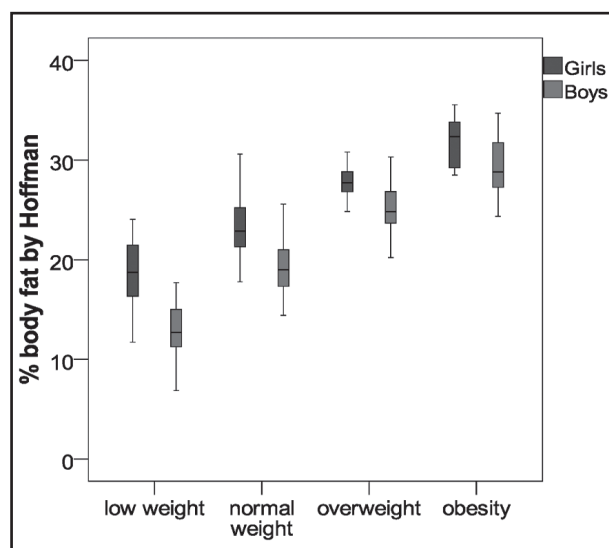


Figure 1.

Body fat percentage by gender and weight status estimated with Hoffman equation.

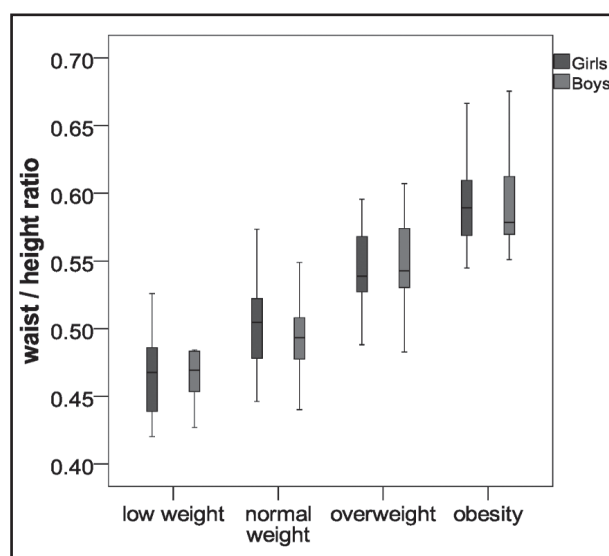


Figure 2.

Waist-to-height ratio by gender and nutritional state.

of clear sexual differentiation at this age. In contrary, Brook and Lukaski and the second Huang equation are the only ones with which no correlations or significant differences with weight status have been obtained. Furthermore, no coherent body fat percentage values have been observed; the first Huang equation seems overvalued these values when moving between 26.8% and 44.3% of body fat. Equally, both Dezenberg equations render seemingly inconsistent results, moving between 4.9% and 29.0%. They are a low percentages of body fat since it is thinness children but without an extreme degree of malnutrition (BMI Z-Score < -0.99).

Other authors, in a study of older children, also highlighted the suitability of the Hoffman equation in comparison with Goran, Slaughter and Huang equations (22).

Although, there are studies that conclude that the different Huang equations obtain more accurate results than the Dezenberg (25), other claim that the first Dezenberg equation used underestimates the total body fat percentage (21,25), while the second one overestimate it in a comparison between both or with BIA or DEXA results (21). Also in comparison with BIA or DEXA, the Slaughter equation overestimates total body fat (25) or obtains similar results (5). At the same time, to determine the most adequate equation to estimate the body fat percentage in 10-to-14-year-old Spanish children has been recommended (7). Body fat results obtained using skinfolds are usually compared with those obtained by DEXA or MRI because it has proven to be the most reliable and sensitive methods (13,16,18,19,26,27).

Discrepancies between these studies and the present study may be due to studies cited were published mostly before the Hoffman equation existed and it was tested in older children (7,25,33).

Waist-to-height ratio has been effective in estimation determining abdominal obesity as has been observed in higher samples and other populations (35,36). In addition, its easy application has been demonstrated because it does not need a highly trained researcher or health professional and it is the best predictor to obesity-associated diseases such as cardiovascular disease and type 2 diabetes (36,37).

BMI Z-Score, skinfolds and waist-to-height ratio are suitable parameters to diagnose childhood obesity (21,36,38,39). Nevertheless, unifying criteria for use of the formulas for the determination of total body fat in children is considered necessary, just as other authors have concluded (21,33).

Childhood overweight and obesity prevalence was 26%, coinciding with 23 international studies (37).

This paper provides evidence on the validity of different formulas for determining body composition in southeast Spanish early childhood from middle and low socioeconomic status. Its importance is due to the wide variety of equations that are present for this purpose in the literature, the few studies on this age population and the difficulty of determining body composition in preschool by the inadequacy or inaccessibility or better predictors of body fat; as DEXA or BIA (21,38-40). The use of skinfolds and their conversion into body fat percentage, along with the measurement of waist-to-height ratio can be useful in screening for overweight and obesity, complementing the Z-Score BMI. It could be helpful for the diagnosis and monitoring childhood obesity in primary care, with no initial need for more accurate methods but much more expensive and aggressive for the child.

The main limitation of this study is that it was performed in a small town and that these results have not been extrapolated to the general population in this age range, the study replication in other communities would be necessary. In contrast, note the very high participation, a percentage greater than 70% of all children in this age group in the population studied.

The most significant contribution is the comparison between the different equations and/or ratios for determining body composition in Spanish preschool children, population so far little present in the literature.

ETHICAL STANDARDS

All human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Also, all people gave their informed consent prior to their inclusion in the study.

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