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Assessing obesity with body weight and height

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Anthropometric measurements in one hundred girls and one hundred boys from 4.6 to 5.5 years of age were carried out in order to study the correspondence between the criteria of obesity according to weight for stature (BW–HT) and according to the magnitude of fat body mass (FM calculated of two different regression equations, one developed starting from body weight (BW), height (HT) and two skinfolds, and another one, using only BW and HT.

Employing the criterion of obesity based upon BW–HT above 120%, a number of heavy but not fatty subjects (mainly boys) were included as obese, and three of the girls studied were fatty but not overweight. Conversely, if we calculate FM using the regression equation based on BW and HT, and the criterion of obesity based upon body fat percent, the incidence of obesity could be underestimated. The best results were given by regression equations which include BW, HT and two skinfolds (triceps and subscapular).

Though the usefulness of BW and HT in nutritional assessment is not discussed, the diagnostic limitations of these measurements used alone or in combination are evident and therefore it is necessary to include skinfold measurements if we wish to obtain a correct diagnosis of obesity.

Since body weight (BW) can significantly be influenced by body length or stature (HT), the use of weight for age for the assessment of the nutritional status in children has been progressively substituted by indices which combine BW and HT in different manners [21, 23, 34].

The most commonly used indices are weight for length or stature (BW–HT), which is expressed as the percentual value of expected weight for actual length [7, 9, 11, 21, 23, 34]; the ratio BW/HT [1, 26], or quantity of body mass per unit of linear dimension; the Ponderal Index, which converts BW in linear dimension [1, 32]; and those indices which establish an age independent relation between BW and height, like Rao's [30] and Dugdale's [12] indices.

Though all these indices are based upon simple measurements, some of them introduce mathematical procedures which complicate the determinations without a significant increase of diagnostic accuracy. None of these methods is capable to express the variations in body composition; they only show the changes in whole body mass, that in a strict sense is not enough to appraise the magnitude of malnutrition and often leads to confusion and misunderstanding of the actual nutritional status [5].

Obesity is the type of malnutrition characterized by an increase of fat body mass (FM) [24], though in most children with hyperplastic forms of obesity there is also an increase of fat-free mass (FFM) [16]. Exogenous obesity is characterized by a tendency of the stature to be in the upper percentile fields [19].

The increase of FM and to a lesser extent of FFM determines the increase of BW in obese subjects, but the increase of BW not always means an increase of FM, especially when the overweight is slight or moderate. Hence, the study of body composition is indispensable for differentiating obese subjects from those who are constitutionally heavy because of their better developed FFM.

In many but by no means in all people a moderately satisfactory estimate of the body fat content can be obtained from BW and HT. For a more precise evaluation several methods are available which give a reasonably accurate measure of FM both in normal subjects and in individuals of unusual body build [14].

Body composition can be assessed by determining FM by linear regression equations developed for the purpose. Dugdale and Griffiths [13] determined several of these equations starting from combinations of anthropometric measurements: BW, HT and skinfolds, and have proved that combining BW, HT and two fatfolds, triceps fatfold (T) and subscapular fatfold (SS), the degree of accuracy compared with the methods using K^{40} is higher than when one or two skinfolds are used alone or combined with BW.

The correspondence between the criteria of obesity according to BW–HT and to the magnitude of FM calculated on the basis of regression equations which use only BW and HT has not been studied. The purpose of the present paper was to examine whether, if only those two measurements are at disposal, it is advantageous to use in the diagnosis of obesity the regression equation instead of BW–HT.

Materials and Methods

One hundred girls and one hundred boys aged from 4.6 to 5.5 years were studied. This sample of two hundred children was selected from among those who attended to polyclinics for periodic health surveillance. None of them had symptoms or a history of chronic disease or malformation.

Data of identity and measurements were obtained by skilled personnel trained at the Department of Physical Development of the Institute of Sports Medicine. These data were:

- Name of the subject,
- Sex,
- Date of birth and date of recording,
- Body weight (BW) in kg, to the nearest 0.1 kg,
- Stature (HT) in cm, to the nearest 0.1 cm,
- Triceps skinfold (T) in mm, to the nearest 0.1 mm,
- Subscapular skinfold (SS) in mm, to the nearest 0.1 mm.

Anthropometric measurements were obtained employing the instruments and following the procedure recommended by the International Biologic Program (36) as described in a previous paper (2).

Decimal age was obtained from the date of birth and the date of recording, following Tanner (36).

Body weight for stature (BW–HT) was calculated according to Ounsted and Simons (27) as follows

$$BW - HT = \frac{A}{B} \times 100$$

where

$$A = \frac{\text{actual weight (kg)}}{\text{actual stature (cm)}}$$

and

$$B = \frac{\text{50th \% expected BW for age (kg)}}{\text{50th \% expected HT for age (cm)}}$$

Expected values for weight and stature corresponded to the 50th percentile of the Cuban National Child Growth Study (22) for the sex and the age of the subject.

Fat body weight (FM) was obtained from the linear regression equations developed by Dugdale and Griffiths (11). We employed two groups of equations: one, which uses BW, HT and two skinfolds (T and SS) as follows:

For boys: FM_1 (in kg) $=1.753+0.304BW - 0.064HT+0.187T+0.140SS$

For girls: FM_1 (in kg) $=7.259+0.647BW - 0.150HT-0.027T+0161SS$

The other equations use only BW and HT according to the expressions:

For boys: FM_2 (in kg) $=5.244+0.380BW-0.085HT$

For girls: FM_2 (in kg) $=7.869+0.650BW-0.151HT$

Body fat percent (or relative fat body weight) (%BF) was obtained from FM by the equation

$$\%BF = \frac{FM \times 100}{BM}$$

Criteria of obesity were established according to BW–HT if the actual BW was 20% or more above the expected BW for stature. According to %BF, obesity was considered if relative fat body weight was 25% or more or 30% or more in boys and in girls, respectively, according to Bray (8).

Mean values and standard deviations for FM_1 and FM_2 in each sex, and for BW–HT were obtained. Means were compared by Student's t test. Correlations between $\%BF_1$ and BW–HT $\%BF_2$ and BW–HT, FM_1 and BW–HT and FM_2 and BW–HT and between FM_1 and FM_2 were calculated and linear regression equations were drawn.

All the subjects considered obese by the BW–HT criterion were cross-classified as obese and non-obese according to their relative fat body weight (%BF) determined by the two previously described regression equations ($\%BF_1$ and $\%BF_2$). A McNemar test was then carried out with the purpose of establishing whether the two methods led to the same conclusion concerning obesity or non-obesity. This test was performed for both boys and girls.

A paired-sample test was performed to compare both methods of determination of %BF for both boys and girls.

Finally, a simple linear regression model was fitted by the least square procedure to the value of $\%BF_1$ and $\%BF_2$ in boys as well as in girls. The statistical hypothesis that b (the slope) was one and that a (the intercept) was zero, was also tested

Results

Mean values for each variable were obtained as shown in Table I. No significant differences were found between FM_1 and FM_2 in boys, while in girls differences were slightly above the significance level ($\alpha = 0.05$). FM_1 as well as FM_2 values were significantly higher in girls, but while in females a slight difference between means could be found, in boys no significant differences were obtained.

TABLE I

Mean ±SD weight for stature and fat body weight in 100 boys and 100 girls aged 5 years

	Mean ± S.D.	Student's *t* test
Boys		
FM_1, kg	3.06± 1.22	5.310 ($p < 0.001$)*
FM_2, kg	3.05± 0.90	1.929 ($p < 0.05$)**
		3.539 ($p < 0.001$)*
BW–HT	103.91±12.57	0.134 (n.s.)*
Girls		
FM_1, kg	4.16± 1.66	
FM_2, kg	3.71± 1.62	0.066 (n.s.)**
BW–HT	106.31±12.59	

FM_1 = Fat body weight obtained by regression equations using body weight, stature and two skinfolds.
FM_2 = Fat body weight obtained by regression equations using body weight and stature.
BW–HT = Body weight for stature.
* Differences in females.
** Differences between FM_1 and FM_2.

Values for BW–HT were similar in both sexes.

Correlation studies are summarized in Table II. All combinations proved to be highly significant, with the *r* values were higher in girls.

Figures 1 and 2 show the dispersion diagram, correlation study and regression line between BF_1 and BW–HT in boys and girls respectively. Cut-off points were drawn defining the limits for the criteria of obesity according to BW–HT (120% of expected weight for stature) and according to %BF (25% for boys and 30% for girls). In Fig. 1 it is possible to observe that, though in 14 subjects BW–HT was above 120%, only 4 of them showed a proportion of body fat exceeding the limit established for the employed criterion of obesity. In girls, the discrepancy was not so manifest, and from 14 overweights (above 120% BW–HT), eleven were also fatty (more than 30% BF), as shown in Fig. 2.

Table III shows the cross-classification of male and female children as obese and non-obese according to both methods of determination of relative fat body weight (%BF_1 and %BF_2). The results of the McNemar test also appear in Table III.

Table IV contains the mean ±S.D. percentage of fat body weight by the two methods and the value of the

TABLE II

Correlations between anthropometric indices of fatness of overweight in 100 boys and 100 girls aged 5 years

x	y	Regression equation $y = bx + a$	Correlation coefficient r*
Boys			
FM_1		$y = 8.84x + 70.87$	0.859
FM_2	BW–HT	$y = 12.78x + 64.92$	0.917
FM_1	FM_2	$y = 0.65x + 1.06$	0.878
$\%BF_1$	BW–HT	$y = 2.02x + 70.48$	0.730
$\%BF_2$	BW–HT	$y = 1.93x + 58.22$	0.757
Girls			
FM_1	BW–HT	$y = 6.30 + 80.71$	0.878
FM_2	BW–HT	$y = 8.37x + 7.541$	0.967
FM_1	FM_2	$y = 0.85x + 0.16$	0.71
$\%BF_1$	BW–HT	$y = 1.87x + 63.57$	0.930
$\%BF_2$	BW–HT	$y = 2.08x + 60.43$	0.823

* All correlation coefficients were significant at the level of $\alpha = 0.001$.

FM_1 and $\%BF_1$: Fat body weight and body fat percent obtained by regression equations using body weight, stature and two skinfolds.

FM_2 and $\%BF_2$: Fat body weight and body fat percent obtained by regression equations using body weight and stature.

BW–HT: Body weight for stature.

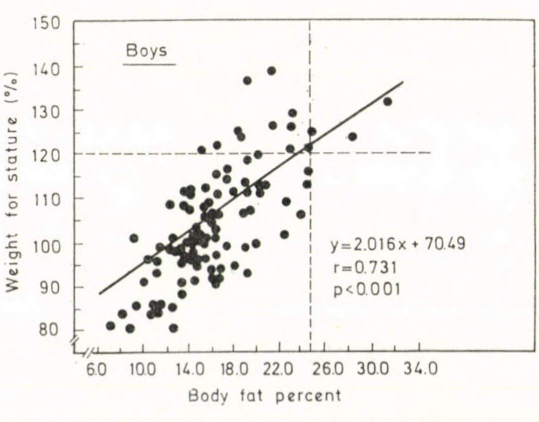

FIG. 1. Correlation between body fat percent obtained from fat body mass calculated from body weight, stature and two skinfolds and weight for stature in 100 five-year old boys. Note that from 14 overweight (above 120% BW–HT) children, only 4 show overfatness

paired sample test in boys and girls.

Finally, Table V shows the values of the parameters and the correlation coefficient corresponding to the fitted linear regression model for each sex.

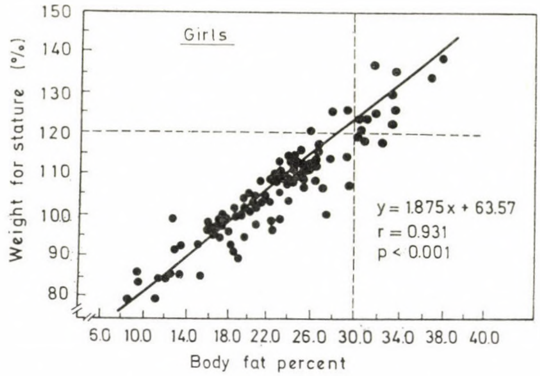

FIG. 2. Correlation between body fat percent obtained from fat body mass calculated from body weight, stature and two skinfolds, and weight for stature in 100 five-year old girls. Note that from 14 overweight (above 120% BW–HT) children, 11 are actually fat and another three fat girls are not overweight

TABLE III

Cross-classification of 14 boys and 14 girls with weight for stature above 120% according to their relative fat body weight (%BF) obtained by two different regression equations

Boys		Relative fat body weight (%BF_1)	
		<25%	≥25%
Relative fat body	<25%	10	4
weight (%BF_2)	⩾25%	0	0

McNemar test = 2.25 (n. s.)

Girls		Relative fat body weight (%BF_1)	
		<30%	≥30%
Relative fat body	<30%	3	5
weight (%BF_2)	⩾30%	0	6

McNemar test = 3.20 (n. s.)

%BF_1: Relative fat body weight calculated from body weight, stature and two skinfolds.
%BF_2: Relative fat body weight calculated from body weight and stature.

TABLE IV

Paired sample test: Mean ± SD body fat percent obtained by two different methods in 5-year old children

Sex	$\%BF_1$	$\%BF_2$	Paired sample test
	Mean ± S.D.	Mean ± S.D.	
Girls			
(n = 100)	22.79±6.25	20.34±5.49	11.216 ($p < 0.001$)
Boys			
(n = 100)	16.57±4.56	16.57±2.60	0.004 (n.s.)

$\%BF_1$: Relative fat body weight (Body fat percent) calculated from body weight, stature and two skinfolds.
$\%BF_2$: Relative fat body weight (body fat percent) calculated from body weight and stature.

TABLE V

Parameters of the fitted linear regressions to the values of body fat percent obtained by two different regression equations in 5-year old children

Parameter	Boys (n = 100)	Girls (n = 100)
Slope (g)	1.30	1.07
Intercept (a)	−5.07	1.04
Correlation Coefficient r	0.74	0.94
Test value for slope ($b = 1$)	2.54 ($p < 0.05$)	1.78 (n.s.)
	from:	from:
Confidence interval for a	−9.03 to −1.13	−0.43 to 0.43

DISCUSSION

Because BW and HT are easily obtainable measurements, many authors stress the importance of these anthropometric indicators in nutritional assessment [31], and many different definitions, equations and formulas for weight for height have been employed [25, 29, 33, 35]. Poskitt and Cole [29] used both the weight/height ratio and the weight-for-height standards to assess obesity in children, arriving at contradictory conclusions when comparing both methods. Hermelo et al. [20] correlated weight for height with weight/height in 184 healthy infants and children, finding a highly significant correlation coefficient (0.931) for the differences between both methods apparent for underweight children, but not for overweight ones. Weight/height has been widely used in adults for assessing obesity [10].

According to Dugdale and Griffiths [11], the estimation of FM based on BW and HT produces highly significant correlations in both sexes. The addition of triceps skinfold to the regression equation meant only a slight improvement that did not reach statistical significance, while the inclusion of further skinfolds to these equations made almost no difference in the percentage of variance. Finally, these authors concluded that the addition of triceps skinfold reduced the number of large errors in the estimates, especially in children who are unusually stocky or "long and lean".

If we take into account the values of FM_1 and FM_2 obtained in boys and in girls, we should assume that, as the differences are very slight or do not exist, and the correlation coefficients are so highly significant, the calculation of fat body mass does not need skinfold measurements and for practical purposes can be done easily by regression equations including only BW and HT. Still, as fat body mass increases, the correspondence between the two methods decreases (Amador et al., unpublished data).

It has been widely demonstrated that, using weight for stature above 120% as the criterion of obesity, the number of "obese" subjects is overestimated, because it includes overweight subjects who are not fat. Regarding the methods for calculating body fat by regression equations, the results of the McNemar test show no significant difference between both methods of determination as regards the classification of obese and non-obese. The discrepancy appears to be high especially in girls, but is not sufficiently so for significance. However, the mean values of the two methods differ significantly in girls, being higher for the method taking into account the skinfolds.

The fitted regression models show very strong correlations between the two methods for $\%BF_1$ and $\%BF_2$ as we found between FM_1 and FM_2. This correlation is higher in girls where the two parameters do not differ significantly from 1 and 0, respectively. In boys, however, the regression line shows that for values of $\%BF_2$ above roughly 17 (in fact, 16.842) $\%BF_1$ tends to be higher than $\%BF_2$ while the relation is reversed for values below 17.

These results led us to assume that the two methods are not indistinguishable even in girls in spite of the fact that b and a do not differ significantly from 1 and 0, respectively. The values of b and a however show that $\%BF_1$ tends to be systematically higher than those of $\%BF_2$ for any value of the latter and this is reflected in the significant differences obtained by the test for comparison of means.

Taking into account the above considerations, we could assume that the use of BW and HT for assessing obesity leads to an overdiagnosis if we use the weight for height criterion, and probably leads to underdiagnosis if we apply the regression equations for calculating FM without including skinfolds.

According to our findings, if we wish to assess fatness, we must include some fat measurement to increase the sensitivity and reliability of the method employed, and the higher the number of fatfolds we include, the higher the accuracy of the method, though for practical purposes two skinfolds seem reliable enough [13, 25].

Though the quantity of subcutaneous fat related to the total body fat [17] is lower in girls than in boys, the *r* coefficients obtained when correlating FM or %BF with BW–HT were higher in females, the opposite to what we had expected. One explanation of this controversial finding could be that boys are more likely to exhibit an overweight due to the increase of fat-free mass, while in girls the increase in BW is frequently related to fatness. In three of our girls $\%BF_1$ was above 30% and BW–HT was under 120% (Fig. 2), a fact that supports our opinion that it is necessary to include fatfold measurements in the assessment of obesity, because in some cases body tissues can be replaced by fat and obesity may be present without any significant change in body mass [18].

Although we arrived at the conclusion that the definition of childhood obesity is a difficult task [6], we believe that the main fact is to keep in mind the limitations of the methods [4]. The diagnostic limitations of using BW and HT grow with the age of the child, and if we are dealing with a moderately overweight patient it is very important to define precisely how fat in fact he or she is before making a hasty diagnosis of obesity. For this purpose, it is evident that we cannot trust parameters like body weight and height alone.

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