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Diagnosing and misdiagnosing malnutrition

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With the purpose of validating new tools as AKS and Energy/Protein Indices for a more precise diagnosis of malnutrition, specially in the case of constitutionally thin or constitutionally heavy subjects which could mistakenly be interpreted as undernourished or obese, two hundred healthy childen, one hundred girls and one hundred boys 4.6 to 5.5 years of age, were studied.

The limitations of weight for stature and the advantages of indicators which determine body composition as accurate measures of malnutrition were demonstrated. In a group of lean individuals with weight for stature under 90%, if E/P figures are under the 10th percentile and AKS is under 1.12, the subject is very likely to be undernourished. In contrast, if the subject, though underweight, shows an E/P Index above the 10th percentile and an AKS over 1.12, constitutional thinness should be considered. In overweight subjects, E/P figures above the 90th percentile point to obesity, while children with E/P between the 10th and 90th percentiles are probably stocky but not fatty subjects.

The usefulness of the combination of the above mentioned criteria in cases suspected to be malnourished, and its introduction in daily practice, will prevent from iatrogenic practices due to erroneous diagnosis.

The problem of diagnosing malnutrition in an individual is very closely linked to the diagnosis of adequate nutrition. Although theoretically the adequacy of nutrition is defined as an equlibrium between needs and intake of energy, the assessment of unbalance is not easy when signs of deficiency are lacking in the case of undernutrition; or when an evident increase of body fat cannot be detected with accuracy if obesity is suspected. The problem has a particular significance when using methods which are not entirely precise to inform about the variation of body composition in patients with early malnutrition [10, 23, 48].

The main effect due to undernutrition on body composition is the loss of fat-free body mass (FFM) [20, 44, 50], while in obesity the outstanding feature is the increase of fat body mass (FM) [26, 43]. These changes cannot be measured by obtaining body weight (BW) alone, because this indicator can be influenced by the variations of body components other than fat and muscle, i.e., water. Furthermore, a light or heavy body constitution could be an individual feature because of minimal adiposity or greater muscularity (the latter can also be acquired by exercise), without meaning either undernutrition or obesity [28, 46, 48].

The development in recent years of regression equations through which it is possible to calculate FM and FFM [10, 11] or indices like the Energy/Protein (E/P) Index [1, 3], capable of reflecting the relationship between FM and FFM starting from single measurements obtained at the middle third of the upper arm, have introduced new tools for the use of clinicians and field workers in individual and community nutritional assessment.

Moreover, some other indices commonly used in anthropologic studies, sports medicine or related sciences are scarcely applied to nutritional assessment though they are able to give good information about body composition. This is the case with the AKS Index, which expresses the weight of FFM contained in a cubic centimeter of body mass [47].

The purpose of this paper is to show the results of the application of some of these methods to nutritional assessment in children in which the diagnosis of malnutrition is controversial when using other anthropometric procedures common in clinical nutrition.

Material and Methods

Two-hundred children, one hundred girls and one hundred boys from 4.6 to 5.5 years of decimal age were studied.

The sample was selected from children attending two Teaching Polyclinics in the city of Havana for periodic health surveillance. Children with chronic diseases or malformations were excluded.

The data were obtained by a measuring team composed of skilled personnel previously trained at the Department of Physical Development of the Institute of Sports Medicine in Havana. 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,
- mid-arm circumference (MAC) 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.

BW, HT, MAC and skinfolds were obtained employing the instruments and following the procedures recommended by the International Biologic Program of the United Nations [51], as described elsewhere [3].

Decimal age was obtained from the date of birth and the date of recording according to Tanner [51]. Body weight for stature (BW/HT) was calculated according to Ounsted and Simons [32]. The standards for BW and HT were those corresponding to the 50th percentile of the charts of the Cuban National Child Growth Study [25] for each sex, at the age of the subject.

The E/P Index was calculated from the equations $E/P = \frac{TT}{\log 10\, MAMC}$ where TT is the transformed T [14], and MAMC the mid-arm muscle circumference, obtained according to Jelliffe from the equation $MAMC = MAC - \pi T$ [24].

Reference values for E/P were obtained from the percentile distribution previously reported by us [3].

Fat body weight (FM) was obtained from the linear regression equations developed by Dugdale and Griffiths [12], for BW, HT and two skinfolds (T and SS), as follows.

For boys under 150 cm stature:

$$FM = 1.753 + 0304BW - 0.064HT + 0.187T + 0.140SS$$

For girls under 140 cm stature:

$$FM = 7.259 + 0.647BW - 0.150HT - 0.027T + 0.161SS$$

From FM given in kg, and BW, body fat percent (%BF) and FFM could be calculated.

The AKS Index was obtained according to Tittel and Wutcherk [47] as

$$AKS = \frac{FFM\,(\text{in g}) \times 100}{HT^3\,(\text{in cm})}$$

Mean values and standard deviations for each variable were calculated, and t tests for comparison of means were performed. Simple linear regression equations were also found when correlating pairs of them.

Results

Mean values and standard deviations for the different variables studied are shown in Table I. Significant differences between sexes were found for E/P, FM and %BF, being higher in girls in all cases.

All correlation studies but one proved to be significant (Table II). Figs 1 and 2 show the correlations between %BF and E/P Index in boys and girls respectively. Regression lines were also drawn and in both cases significant r values were obtained, being higher in boys. In these figures two other aspects must be pointed out: one of them is that in the scatter diagram we divided the individuals into four groups according to BW/HT as follows. Obese

Table I

Mean and standard deviations for several indicators used in nutritional assessment of children 4.6 to 5.5. years old

Indicator	Girls		Boys		t value p
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	
A.K.S. index	1.19	0.08	1.22	0.09	0.589 n.s.
Energy/protein index	1.697	0.124	1.638	0.129	3.269 <0.005
Body fat per cent	22.79	6.25	16.58	4.55	7.980 <0.001
Kilograms of body fat	4.16	1.66	3.06	1.22	5.291 <0.001
Weight for stature	106.31	12.59	103.91	12.57	1.338 n.s.

Level of significance: $\alpha = 0.05$.
Number of subjects: Girls: N = 100
Boys: N = 100

TABLE II

Correlation studies between pairs of indicators in children 4.6 to 5.5 years old

Girls (N = 100)		Regression equations	r	p
x	y			
AKS index	E/P index	$y = 0.676x + 0.89$	0.414	<0.001
%BF	E/P index	$y = 0.014x + 1.38$	0.706	<0.001
AKS index	BW/HT	$y = 72.066x + 20.17$	0.436	<0.001
Boys (N = 100)		**Regression equations**	**r**	**p**
x	y			
AKS index	E/P index	$y = 0.221x + 1.37$	0.164	n.s.
%BF	E/P index	$y = 0.024x + 1.23$	0.857	<0.001
AKS index	BW/HT	$y = 91.525x + 7.58$	0.701	<0.001

Level of significance: $\alpha = 0.05$.
E/P = Energy/Protein index
%BF = Body fat per cent
BW/HT = Body weight for stature

(BW/HT > 120%); overweight (BW/HT 111–120%); mean weights (BW/HT 91–110%); and underweight (BW/HT ≤ 90%). The other aspect is that the cut-off lines for the 90th and 10th percentiles for E/P and for the conventional limit of obesity (20 and 30 %BF) [4, 7] were drawn in the Figure.

It is evident that an important number of subjects classified as overweight or obese according to BW/HT

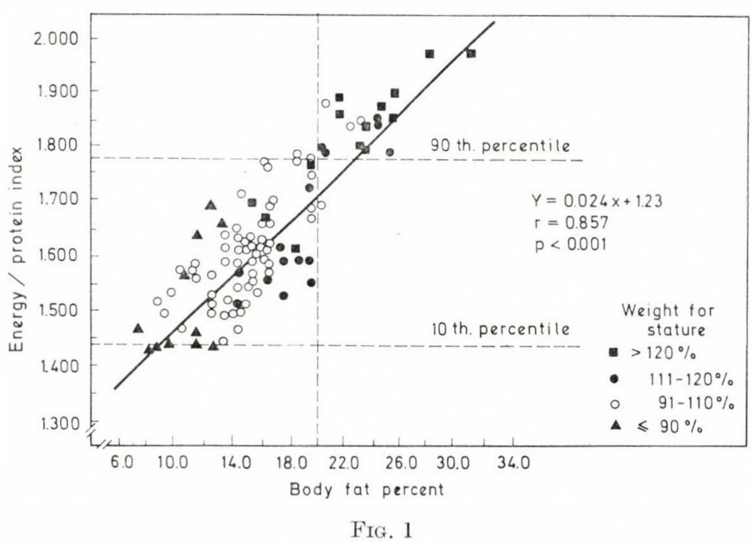

FIG. 1

were not actually obese according to their FM, showing E/P values under the 90th percentile; and the opposite situation, few fatty individuals were not overweight, showing E/P values above the 90th percentile. On the other hand, children classified as underweight (BW/HT $\leq 90\%$) were neatly grouped into two categories: those who are very near or below the cut-off line of the 10th percentile for E/P, and those who are clearly above this line.

Figures 3 and 4 show the correlations between the two indices AKS and E/P. The results differed from one sex to the other, the r values being significant only in girls, although the distribution of the subjects was much more disperse than in Figure 2. The dispersion was also notable in children over 120% BW/

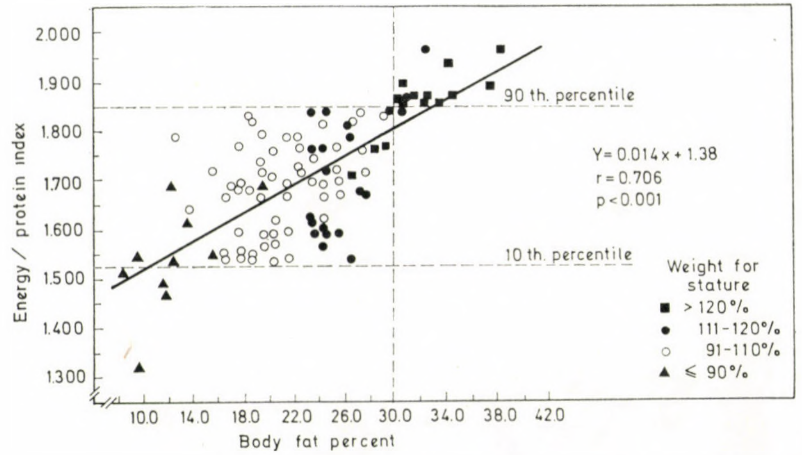

FIG. 2

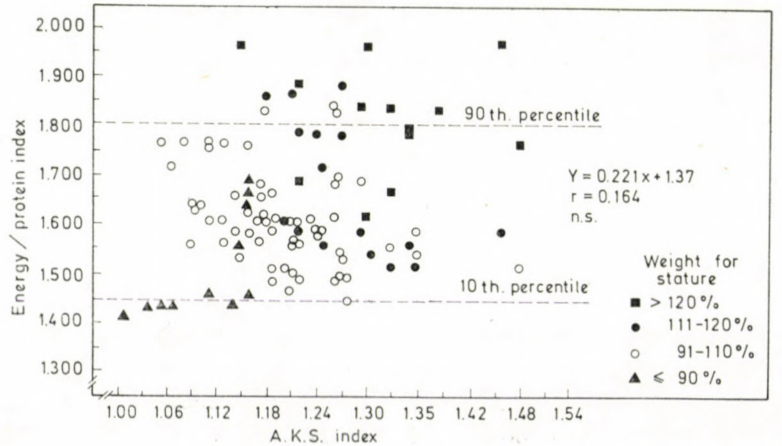

FIG. 3

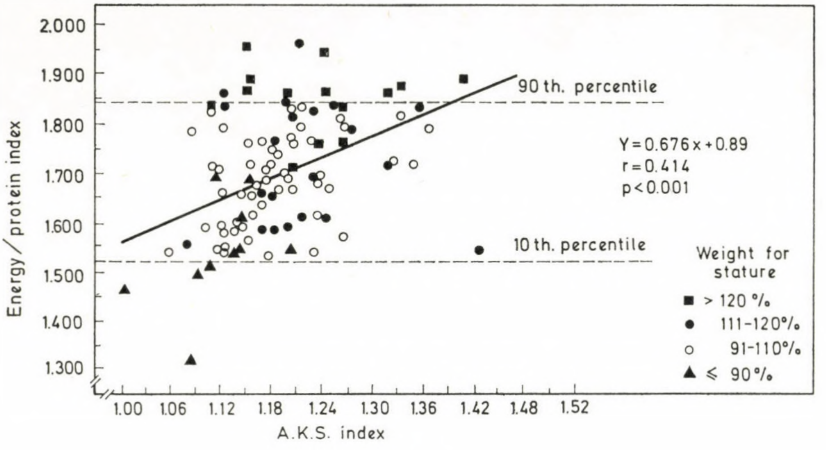

FIG. 4

HT, with a very wide range of values for AKS, especially in boys. Once again we have focussed our attention on the thin children previously reported in Figs 1 and 2. We could find a correspondence between low E/P and low AKS figures. Most of the children, boys as well as girls, with AKS under 1.12 had E/P values at or below the 10th percentile.

Discussion

Nutritional adequacy is now considered an important factor in the life of an individual from the time of gestation to the time of his acceptance of full responsibility as a socially functioning adult [11]. This adequacy is evaluated according to the equilibrium between energy and nutrient needs and intake. We could say with Greaves and Berry [18] that "nutritional status is that condition of health of people that can be attributed to the foods they habitually consume". Traditionally, concern with nutritional status has been focussed chiefly on the identification and measurement of undernutrition, but the definition suggested clearly implies that problems arising from overnutrition should also be considered.

The limitations of HT and BW as indices of growth performance are well recognized, yet they continue to be used because of ready availability and ease of measurement [15]. Every physician on the other hand recognizes the fact that children differ in body build as do adults, and although it is true that generally an increase of BW expresses an increase of fat, in other cases there is an increase in BW at muscle expense, and this means not to be more fatty but more muscular [16].

If we consider body mass to be distributed into two compartments of relatively constant composition: FM and FFM [13], it is evident that the increase of both components with age in children does not contribute in the same proportion to the increase of overall size of the body. These changes are influenced not only by age and sex, but also by constitutional peculiarities [19], and variations in balance between input and output of energy (physical activity included), have an influence upon these changes [35, 40]. For this reason, our sample was classified according to sex and our study was restricted to children in the range from 4.6 to 5.5 years of age in order to avoid two factors of variation.

Though the limitations of regression equations in predicting FM and FFM are well-known, they have proved to reflect with more accuracy the degree of fatness or leanness than those indicators which use only BW and length or stature [8, 17, 31]. Recent studies by Hermelo et al. demonstrated that there is a highly significant correlation between two different criteria of classification of malnutrition which use weight for height or the ratio weight/height [23]. We have also found a significant correlation between %BF and BW/HT ($r = 0.931$ in girls and $r = 0.731$ in boys of preschool age) [6], but we could demonstrate that overweight is not always coincident with fatness. Peña et al. [39] demonstrated that in obese children the quantitative information offered by BW/HT is not always proportional to the actual fat mass, and may even be paradoxical. This discrepancy could be demonstrated in the present paper too, and not only among overweight or obese children, but also among lean or underweight ones.

As we have no own figures for our population, we have used Dugdale and Griffiths's regression equations for BW, HT and two skinfolds (T and SS) [12]. The results obtained are satisfactory enough for our purposes and they are comparable to those obtained by other authors using different methods [9, 27, 45], though there are not many reports about body composition in preschool children.

We agree with Dugdale and Griffiths [12] that, combining BW, HT and fatfolds, the possibilities of error arising from the use of regression equations based upon skinfolds alone or using BW and skinfolds [27], are quite low.

Once again, the usefulness of the E/P Index for nutritional assessment has been demonstrated, and a close correspondence could be found between %BF and E/P, similar as that obtained in trained, non trained and obese schoolboys [5]. Though highly significant in both sexes, r figures were higher in boys, exactly opposite to our previous findings, when correlating %BF with BW/HT [6]. These variations could be attributed to the sexual differences in fat distribution and FFM development present since early childhood [29, 33, 34, 37, 42].

It is clear that, according to our results, there are two groups of underweight children who differ in body composition: one of them showing E/P figures above the 10th percentile and an AKS Index above 1.12; and another group with E/P figures below the 10th percentile and an AKS below 1.12. In other words; both groups are composed by lean children, but in the second one, the FFM is significantly lower.

The correlation between AKS and E/P is not significant in boys; in girls, though significant, the values show a fair scattering. The constitutional differences in the development of FFM seem to be responsible for these findings, more evident in boys who, at the age studied, differ from girls in their rapid growth of muscle mass [37, 38]. Though in severely undernourished children BW decreases significantly at the expense of FFM, in mild or moderate forms there is no such a correspondence [21], meanwhile AKS seems to show a higher sensitivity, proving useful in the determination of the degree of development of FFM, when the decrease of muscle mass due to undernutrition results in a low AKS figure. Thus, this Index is applicable not only in sports medicine but also for nutritional assessment.

If we accept the reliability of the calculation of FFM through the regression equations and we take into account our previous results validating the E/P Index as a useful tool in the evaluation of the nutritional status [2, 4], we may conclude that the diagnosis of malnutrition can be made with more accuracy if we include these indicators (E/P and AKS Indices) as complementary tools among those commonly used in field studies or in clinical practice.

This is particularly important when, after an initial screening based upon body weight, we segregate groups of "atypical" subjects among whom it is necessary to determine exactly which of them are actually malnourished. Thus, in a group of lean individuals it is important to know which are undernourished and which are constitutionally thin, and, on the other hand, in a group of stocky subjects, who are obese and who are constitutionally heavy. Thus at least in five-year old children, in the first case those who have E/P figures below the 10th percentile and AKS under 1.12 are very likely to be undernourished, because they combine three criteria: underweight, low fat/muscle ratio (as expressed by E/P), and low FFM (as expressed by AKS). Therefore, those with an E/P over the 10th percentile and AKS above 1.12 are probably not undernourished, but constitutionally thin or "light".

In the second case, "heavy" or overweight children with E/P values between 10th and 90th percentiles are very likely not to be obese.

Several authors have been working in the same direction. Reiken et al [41] developed a somatogram combining HT, BW and three skinfolds which permits to differentiate between overweight and overnutrition or obesity. Mueller and Wohlleb [30] have made an analysis of body build and fat distribution which seems to be useful in the assessment of obesity. We ourselves have proposed to combine several non-costumary criteria for the diagnosis of malnutrition, especially in borderline cases.

Recently, Habicht [22] commenting on a paper by Trowbridge and Staehling [49] said that the main fact to have in mind when assessing the nutritional status is that the indicators must be chosen according to the type and degree of malnutrition, time of evolution, and several other factors, and therefore previous to any study it is necessary to establish what we are looking for. If we apply schematically the same pattern to every condition, the possibility of misdiagnosing malnutrition will highly increase.

Coincident with this point of view, we have focussed our attention on a group of children prone to be involved in inadequate management because of a peculiar body constitution misdiagnosed as malnutrition. The possibility of giving a reliable definition to an anxious family worried about a thin or heavy child suspected to be malnourished, makes worthy the effort in using the proposed additional criteria.

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