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ENERGY/PROTEIN INDEX: ITS USEFULNESS IN ASSESSING OBESITY

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ABSTRACT: The values for Energy/Protein Index (E/P) in selected samples of 120 healthy school children aged 8–14 years (53 boys and 67 girls) and in 78 healthy young adults aged 17–19 years (30 men and 48 women), were obtained. Correlations with body fat percent and the ratio Fat/Lean Body Mass were highly significant, and a high degree of association between E/P and several variables used as criterion of obesity like body weight for height, body weight for age, body weight percentile, body fat percent and triceps skinfold percentile was also demonstrated. Cut-off values for E/P of 1,500 for boys and young men, and of 1,650 and 1,700 for girls and young women respectively, were established as limits above which obesity could be diagnosed with accuracy.

Our present results prove that E/P — which is the ratio between transformed triceps skinfold and the $\log_{10}$ of mid-arm muscle circumference — is a reliable indicator for assessing obesity and for establishing the differences between "constitutionally heavy" and true obese subjects. E/P gives similar information than body fat percent through two simple measurements, and it is much more reliable than those measurements like body weight or arm circumference which can only appraise variations in whole body mass and not in body composition.

Key words: Energy/Protein Index, obesity, body composition.

Introduction

Energy/Protein Index (E/P) has been defined as the ratio between transformed fatfold at triceps (TTS) and the logarithm of mid-arm muscle circumference (TMAMC) (AMADOR et al. 1975). Further studies have demonstrated that there is a close relationship of E/P figures with adiposity and that these are significantly higher in overweight subjects than in lean ones (AMADOR et al. 1976).

Although several criteria for diagnosing obesity have been defined, difficulties still arise when overweight is due to the developing of fat-free mass (FFM) (FORBES 1964) and the somatometric measurements which appraise the variations in whole body mass, — like body weight (for age or for height) and mid-arm circumference (MAC) — are considered for classification (GARN, CLARK and GUIRE 1975).

The study of fatfolds approaches more closely to the actual energy status (Committee on Nutrition, 1968), and the percentile distribution of triceps skinfold has proven to be very useful for this purpose, being also rather easy to obtain this measure from the subject. E/P relates adiposity to muscle mass at the level of the mid-arm and therefore gives information about the status of the two components of body mass: adipose tissue and fat-free mass, both affected in obese individuals; hence, it has been our aim to deep into the qualities of E/P for the assessment of obesity.

Material and methods

A selected sample of 120 healthy school children (53 boys and 67 girls) was obtained from those attending the Teaching Polyclinic "Playa" in Havana, for periodical surveillance. Their ages ranged from 8 to 14 years. Another selected sample of 78 healthy young adults aged 17—19 years (30 men and 48 women), was obtained from first and second year medical students attending the Institute of Basic Sciences "Victoria de Girón" (ISCMH) in Havana.

Somatometric measurements were performed by skilled personnel previously trained in the Department of Physical Development of the Institute of Sports Medicine, according to the methodology recommended by the UNO International Biologic Programme (IBP) (WEINER and LOURIE 1969; WHO/NUTR., 1970), and by the International Child Center, Paris (FALKNER 1960). This methodology was also employed in the National Child Growth Study (JORDÁN et al. 1975).

The measurements obtained were: body weight, stature, MAC, triceps skinfold (TS), biceps skinfold (BS), subscapular skinfold (SES), suprailiac skinfold (SIS) and calf skinfold (CS). Body weight was measured employing a Herbert and Sons scale with a capacity of 0—155 kg and aprecision up to 0,1 kg. Stature was obtained using a Holtain portable stadiometer with a range 840—2050 mm. Circumferences were measured with a fiberglass tape, one meter long and 15 mm wide with a 10 cm blank leader. Fatfolds were obtained using a Holtain skinfold caliper range 0—45 mm with a standard pressure of 10 g/mm^2. Circumferences, as well as fatfolds were taken from the right hand side of the body.

Starting from MAC and TS values, MAMC was obtained according to the formula (JELLIFFE 1966): $MAMC = MAC - \pi TS$.

The transformation to a log. scale of TS according to the caliper employed is as follows (EDWARDS et al. 1955):

$TTS = \log_{10}$ (reading in 0,1 mm—18).

The E/P Index was calculated by the expression:

$$E/P = \frac{TTS}{TMAMC}.$$

Body fat percent was calculated according to the regression equations for the sum of five skinfolds (TS + BS + SES + SIS + CS), developed by PAŘÍZKOVÁ and ROTH (1972) for school children, and according to DURNIN and RAHAMAN (1967), for young adults. Lean body mass (LBM) was considered as the difference between total body weight and the kilograms of body fat obtained from the percentual value calculated following the regression equations.

Reference values for body weight, height, weight for height and fatfolds were obtained from the standards of Cuban population according to the National Child Growth Study (JORDÁN 1979).

Regression lines and correlation coefficients between E/P figures and different variables were calculated. In order to establish the degree of association between E/P and several variables used as criterion of obesity, χ^2 tests were performed. The median for E/P was calculated for each of the four groups, and in each one, two subgroups were formed: one with E/P above the median, and another with E/P equal or below the median. Each of these subgroups was once more classified according to the different anthropometric criteria for assessing obesity:

Body weight for height (Forbes 1964); Cut-off point, 120% of expected weight for actual height.

Body weight for age (Garn, Clark and Guire 1975): Cut-off point, 120% of expected weight for chronological age.

Body weight percentile (Wilkinson et al. 1977): Cut-off point, 97th percentile.

Body fat percent (Bray and Davidson 1972): Cut-off point, 25% in males (we used 20% in this case), and 30% in females.

TS percentile (Stunkard et al. 1972): Cut-off point, 90th percentile.

Results

Energy/Protein Index figures were correlated to body fat percent both in school children and in young adults. In figures 1, 2, 3 and 4, the regression lines are drawn, and the significant correlation coefficients are shown. The dotted line from the side of the abscissa represents the cut-off point above which the percent of body fat is considered consistent with the criterion of obesity. In females, we have followed Bray and Davidson (1972), considering the cut-off point in 30 per cent, but in males we established the cut-off point in 20 per cent instead of 25. The second dotted line, perpendicular to the ordinates, represents the cut-off point above which E/P figures could be considered consistent with the criterion of obesity. For males, the cut-off point for E/P is 1,500, and for females it is higher, being 1,650 for school girls and 1,700 for young women. As can be seen in the four figures, there is a corre

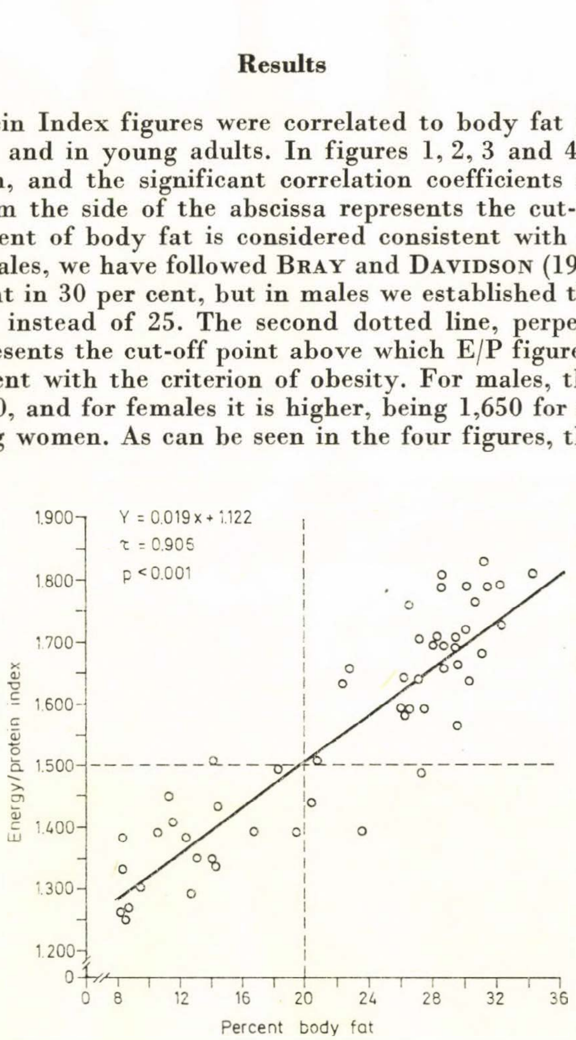

Fig. 1. Correlation between percent body fat and Energy/Protein Index in school boys aged 8–14 years

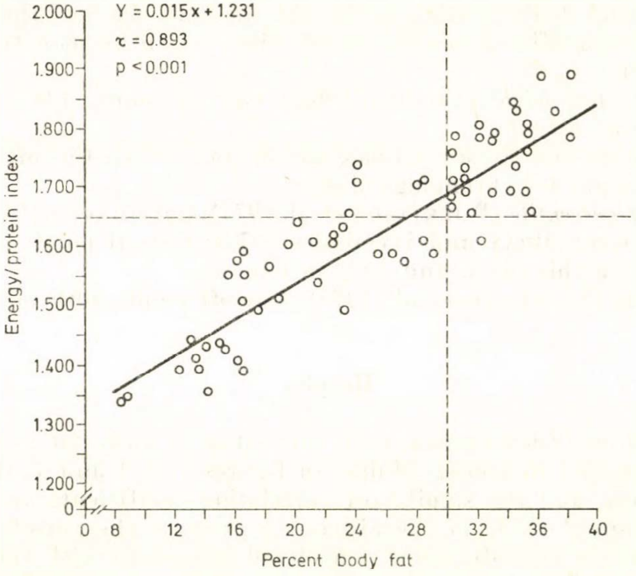

Fig. 2. **Correlation between percent body fat and Energy/Protein Index in school girls aged 8–14 years**

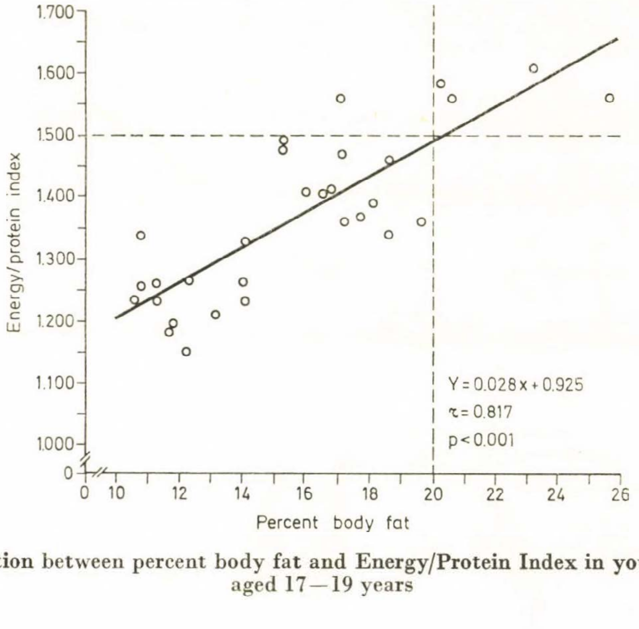

Fig. 3. **Correlation between percent body fat and Energy/Protein Index in young male adults aged 17–19 years**

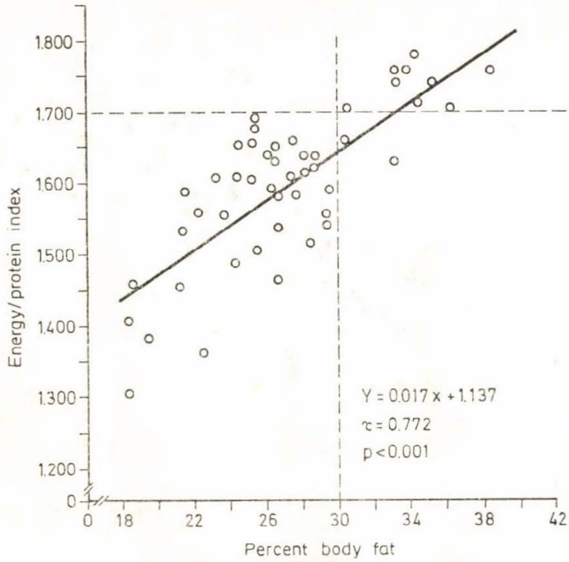

Fig. 4. Correlation between percent body fat and Energy/Protein Index in young female adults aged 17–19 years

spondence between E/P and body fat percent in most of the cases, and the obese subjects, according to both criteria cluster in the upper right quadrant.

Energy/Protein Index was also correlated with the ratio Fat/Lean Body Mass (F/LBM). In this occasion, boys and young men were grouped together (83 subjects) and also we did with girls and young women (115 subjects). In both groups, highly significant correlation coefficients were obtained (Table 1).

Table 1

Correlation between Fat/LBM ratio and Energy/Protein Index in males and females aged 8–19 years

Groups	n	y = ax + b	r	p
Boys and young men	83	$y = 1.37\times + 1.131$	0.900	<0.001
Girls and young women	115	$y = 0.77\times - 0.875$	0.781	<0.001

The results shown above establish the correspondence of E/P values with the relationship of body weight in fat and fat-free mass, which is of great importance in the establishment the diagnosis of obesity with accuracy. The ratio E/P could be therefore considered the local expression, at the mid-arm level, of the ratio F/LBM.

The relationship of E/P with the degree of fatness has been demonstrated in the dispersion graphs of figures 5 and 6, where — as in the previous case — age groups were gathered according to sex. In both figures, subjects are scat-

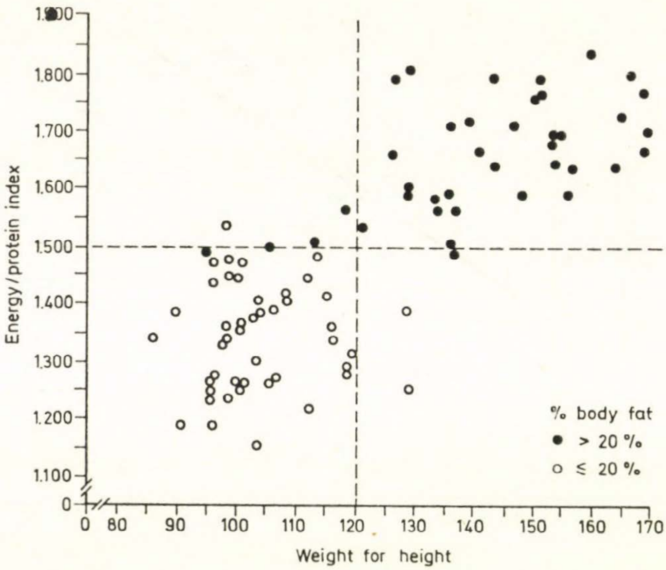

Fig. 5. **Relationship between E/P Index, weight for height and percent body fat in males aged 8—19 years**

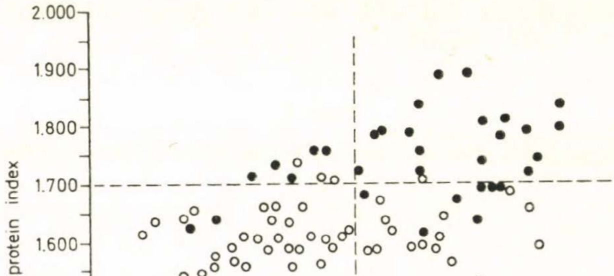

Fig. 6. **Relationship between E/P Index, weight for height and percent body fat in females aged 8—19 years**

tered according to their weight for height and E/P values. Different symbols identify those with body fat percent above the cut-off points (20 or 30 per cent according to sex). As the figures show, obese individuals cluster in the upper right quadrants, and a cut-off line can be defined, corresponding approximately to the same E/P values obtained when correlating E/P with body fat percent. A rather important proportion of individuals with weight for height above 120% (cut-off point for obesity according to this criterion), are below this line, and most of them are not obese according to their body fat percent. Thus, E/P has a better correspondence with body fat than weight for height.

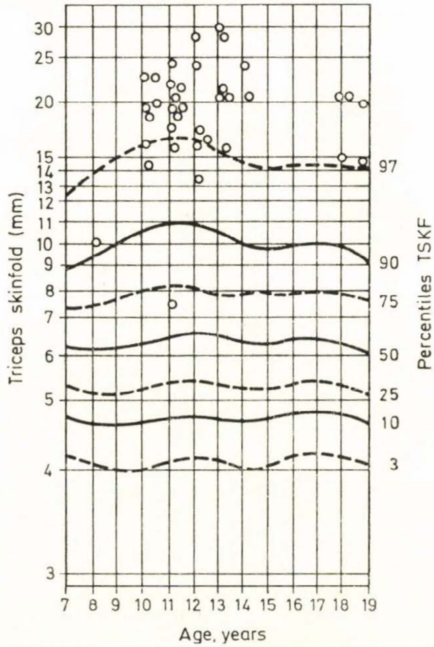

Fig. 7. Distribution of boys and male adolescents with E/P values above 1.500 according to the percentile distribution of triceps skinfold

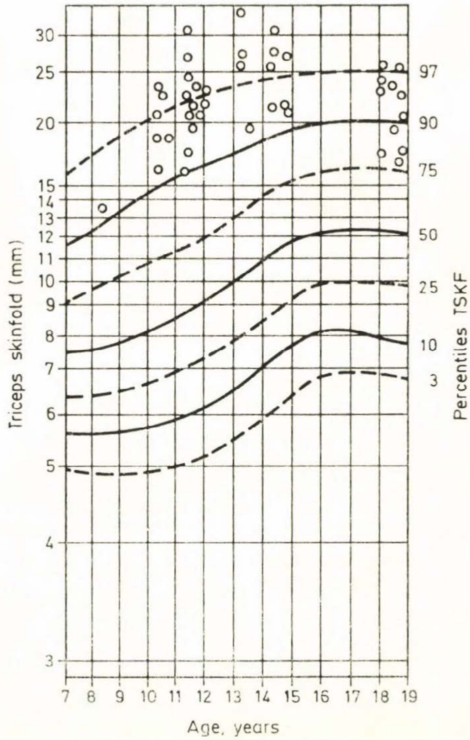

Fig. 8. Distribution of girls and female adolescents with E/P values above 1.650 according to the percentile distribution of triceps skinfold

If we separate those subjects above the cut-off point for E/P value, and we place them in a chart according to their percentile distribution for triceps skinfold, we'll find that almost the total number of them fall above the 90th percentile (Figures 7 and 8).

The results of the χ^2 tests performed in order to establish the degree of association between E/P and several variables used as criteria of obesity appear in Tables 2, 3 and 4, and they proved to be significant.

Table 2

Association of Energy/Protein Index with several variables used in the assessment of obesity School Boys (8—14 years)

Boys	> 20% BF	≤ 20% BF	Total
> Median E/P	27	00	27 $\chi^2 = 33.357$
≤ Median E/P	6	20	26 $p < 0.001$
	33	20	53

	> 90th p TS	≤ 90th p TS	Total
> Median E/P	27	00	27 $\chi^2 = 30.757$
≤ Median E/P	7	19	26 $p < 0.001$
	34	19	53

	> 120% WH	≤ 120% WH	Total
> Median E/P	27	00	27 $\chi^2 = 36.119$
≤ Median E/P	5	21	26 $p < 0.001$
	32	21	53

	> 120% W/AGE	≤ 120% W/AGE	Total
> Median E/P	26	1	27 $\chi^2 = 18.319$
≤ Median E/P	11	15	26 $p < 0.001$
	37	16	53

	> 97th p W	≤ 97th p W	Total
> Median E/P	24	3	27 $\chi^2 = 28.717$
≤ Median EP	4	22	26 $p < 0.001$
	28	25	53

E/P = Energy/Protein Index
BF = Body Fat
WH = Weight for Height
W/AGE = Weight for age
W = Body weight
TS = Triceps skinfold

Table 3

Association of Energy/Protein Index with several variables used in the assessment of obesity
School Girls (8–14 years)

Girls	> 30% BF	≤ 30% BF	Total	
> Median E/P	27	6	33	$\chi^2 = 42.830$
≤ Median E/P	1	33	34	$p < 0.001$
	28	39	67	

	> 90th p TS	≤ 90th p TS	Total	
> Median E/P	31	2	33	$\chi^2 = 42.288$
≤ Median E/P	5	29	34	$p < 0.001$
	36	31	67	

	> 120% WH	≤ 120% WH	Total	
> Median E/P	28	5	33	$\chi^2 = 30.257$
≤ Median E/P	6	28	34	$p < 0.001$
	34	33	67	

	> 120% W/AGE	≤ 120% W/AGE	Total	
> Median E/P	28	5	33	$\chi^2 = 20.964$
≤ Median E/P	10	24	34	$p < 0.001$
	38	29	67	

	> 97th p W	≤ 97th p W	Total	
> Median E/P	27	6	33	$\chi^2 = 36.085$
≤ Median E/P	3	31	34	$p < 0.001$
	30	37	67	

E/P = Energy/Protein Index
BF = Body Fat
WH = Weight for Height
W/AGE = Weight for age
W = Body weight
TS = Triceps skinfold

Table 4

Association of Energy/Protein Index with several variables used in the assessment of obesity
Young Adults (17–19 years)

Females	> 30% BF	≤ 30% BF	Total
> Median E/P	11	13	24 $\chi^2 = 19.556$
≤ Median E/P	0	24	34 $p < 0.001$
	11	37	48

	> 30% BF	≤ 30% BF	Total
> 120% WH	5	12	17 $\chi^2 = 1.272$
≤ 120% WH	6	25	31 n. s.
	11	37	48

Males	> 20% BF	≤ 20% BF	Total
> Median E/P	4	11	15 $\chi^2 = 4.615$
≤ Median E/P	0	15	15 $p < 0.05$
	4	26	30

	> 20% BF	≤ 20% BF	Total
> 120% WH	3	2	5 Test Fisher (PE)
≤ 120% WH	1	24	25 $p = 0.0092$
	4	26	30

E/P = Energy/Protein Index
BF = Body Fat
WH = Weight for Height

Discussion

Energy/Protein Index has been designed with the purpose of obtaining an indicator for the assessment of the nutritional status suitable to evaluate the variations of body components which reflect energy and protein status. This is based on the assumption that, at different ages, these two components (adiposity and muscle mass), represented by fat fold at triceps and MAMC, keep a certain relationship which is peculiar, not only for each age group, but also for each sex. This hypothesis has been confirmed and reported in previous papers (Amador, Bacallao and Flores 1980, Valle and Amador 1981), in preschool children and infants respectively.

The different behaviour of E/P in infants and children classified according to the weight for height as evidenced by the mean values assumed by the Index in overweight, "average" and underweight children, and confirmed by the regression equations (Amador, Bacallao and Flores 1980, Valle and

AMADOR 1981), reinforces the assumption that E/P is closely related with the variations of body mass. Our present results show that this is also applicable to school children and young adults.

Energy/Protein Index is not only related to body mass but also it measures energy reserves (represented by adiposity) and their relation to fat-free mass (represented by muscle mass at mid-arm level). Significant regression coefficients have been found between E/P and mid-arm fat area and between E/P and the ratio Fat Area/Muscle Area at the middle third of the upper arm (AMADOR, RODRÍGUEZ and BACALLAO 1980) and also between E/P and the first component of the somatotype and with E/P and the ratio First/Second components (AMADOR, RODRÍGUEZ and BACALLAO 1979). The significant correlations between E/P and body fat percent are consistent with these findings, and confirm the assertion that we can use this Index as a measure of adiposity, the whilst the correlation between E/P and the ratio F/LBM demonstrates that E/P represents very closely the relationship between adiposity and fat-free mass in the whole body.

Since E/P permits a more precise assessment of body components variations than other widely used methods such as weight and arm circumference, and it can be readily calculated starting from measures which are easier to obtain than those necessary for determining body composition with more accuracy, its use could be advantageous in nutritional assessment. The design of a nomogram for the rapid calculation of E/P (AMADOR, BACALLAO and FLORES 1980), avoids mathematical calculations and permits to obtain the Index directly from TS and MAC figures.

The determination of cut-off points for establishing practical limits between "typical" or "atypical" figures for a given value is a difficult matter, taking into account that a given individual measure has to be compared with some expected value considered normal or usual for the age or sex group and for the individual genetic potential. The cut-off point should be the limit beyond which, the values obtained are more likely to occur out of the distribution of values of a comparison population.

It is a matter of great controversy to determine at which value a subject begins to be atypical for a given measure. BRAY and DAVIDSON (1972) establish the cut-off point for the percent of body fat in 30% for females and 25% in males. In our own experience, the mean value of body fat percent was 15.1% in healthy school boys and 14.2% in young men (HERMELO et al. 1981), figures which are coincident with those obtained by NOVAK (1963), DURNIN and RAHAMAN (1967) and WELTMAN and KATCH (1978). Thus, the value of 25% is, for these figures, too high as a cut-off point, and therefore we choosed 20%, which represents approximately a 20% of overweight in fat above our mean.

The cut-off points for E/P were established at the value 1,500 for males and at the values 1,650 and 1,700 for school girls and young women respectively, corresponding approximately to the 90th percentile for E/P at this age (CANETTI et al. 1981, to be published) and the correspondence between the Index and the percent of body fat could be appreciated in the regression studies.

Although in both sexes, the correlation was highly significant, it was higher in males, we think, due to differences in fat distribution, which is sex dependent (PAŘÍZKOVÁ and ROTH 1972), DURNIN and WOMERSLEY 1974, PAŘÍZKOVÁ 1976).

The few non-corresponding cases could be explained as follows:

— Those with fat percent above the cut-off line and E/P below it, should be subjects with an upper arm muscle mass proportionally more increased than fatfold.

— Those with fat percent below the cut-off line and E/P above it, should be subjects with a specially fatty arm, probably related to genetic or other individual conditions, with relatively low muscle development.

These exceptions do not affect our conclusions, and moreover, they reinforce our assumption that E/P may be used as a practical substitute instead of body fat percent for assessing and quantifying obesity.

Regarding weight for height as an indicator of obesity, a similar situation, perhaps more evident, can be noticed. In males, the correspondence between E/P and weight for height is, like it happened with body fat percent, better than in females. The number of "heavy", non obese females, is higher than the number of "heavy" non obese males. This could seem a contradiction if we look this finding from the point of view that overweight due to muscular development should to be expected to happen more frequently in boys and young men.

As we expected, the subjects with E/P values above the cut-off lines fell almost invariably above the 90th percentiles of TS. Garn, Clark and Guire (1975), consider as obese those subjects above the 85th percentile for TS, but we prefered, according to Stunkard et al. (1972), the 90th percentile as cut-off point for studying the association between E/P and TS.

Seltzer and Mayer (1964) and Knittle (1972) made very clear remarks about the fact that obesity must be only diagnosed when the amount of fat of the body is increased. We had followed this concept and therefore we tried to relate E/P with indicators such as body fat percent and percentile of triceps skinfold. But nevertheless it was also interesting to corroborate how this Index is related with body weight. E/P proved to be associated in more or less degree to weight for age and to the percentile distribution of body weight. But body weight is not itself a reliable measurement for nutritional assessment when considered alone. Garn, Clark and Guire (1975), clearly demonstrated that the 120% of weight for age does not always correspond to the 85th percentile of TS, and moreover, the correspondence changes with age from birth to old age; the correlation coefficients between TS and relative weight, change in a wide range in males as well as in females.

The definition and measurement of obesity is still a difficult and complex task, and yet many studies have to be performed regarding body composition and body build in order to define obesity and differentiate it from overweight present in "constitutionally heavy" individuals. We consider that E/P Index goes a step further in clarifying those aspects.

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