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RELATIONSHIPS OF NUTRITION STATUS AND BODY DIMENSIONS IN A SAMPLE OF HUNGARIAN YOUTH

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Abstract: *By using a recent Hungarian sample of 3331 boys and 5172 girls aged between 7 and 19 age group means, standard deviations and centiles of the body mass index were computed to help assessing the nutrition status of our children. A 10-centile set of curves was constructed. In addition to presenting the raw centiles two kinds of smoothing were applied, exponential and the so-called LMS method of Cole both of which are discussed. The shapes of the centile curve sets are discussed with respect to methodological considerations. The empirical Hungarian set of BMI centiles is compared to that representative of the US. The obtained centiles are intended to serve as preliminary references for the two sexes but not as standards. They are not representative either.*

Keywords: *Body mass index of children; Centile distribution; Smoothing of centile curves; LMS method.*

Introduction

Incorrect dietary habits and an inactive style of life may lead to obesity already in children and adolescents, despite the increased requirements for nutrients in the period of growth. In the developed countries the more frequent form of nutrition imbalance is excessive calorie input. In the development of obesity one has to reckon also with hereditary factors (Susanne 1975, Mueller 1983, Roche 1992) besides such environmental contributors as long-term dietary disorder and lack of exercise (Garn, Cole and Bailey 1979). The observation that more than a half of Hungarian adult males classified as overweight or obese (Bíró 1994) reflects the severity of the problem.

The goal of the present authors was to construct empirical centiles of the body mass index that could be used for assessing the nutrition status of Hungarian school-age children. Nutrition status is an attribute estimated by some metric indicator. The ranges by which individuals or groups are classified as too lean or too fat to be healthy or as ones in whom the required amount of energy is balanced by nutrient intake are usually set by general agreement.

Quételet's index (Quételet 1831) or Kaup's index (Kaup 1921), known as the body mass index in the English references, has commonly been used not only for estimating preferred body mass, but also for classifying obesity, respectively nutrition status (Eiben et al. 1991, Hammer et al. 1991, Joubert et al. 1992, Bláha et al. 1994, Singh 1996, Bodzsár 1999, 2001, Rebato et al. 2002). The body mass index (BMI) has also been used in epidemiological studies, and its adult values (WHO 1969, 1996), respectively their interpretation (Pietrobelli et al. 1998, Ross and Eiben 2002) has been the focus of a good number of reports. However, little is known about its variation by age and sex in childhood and adolescence, there are no generally recognized ranges or cut offs for counselling, but merely certain guidelines for some countries where BMI is used to estimate nutrition status (Cole et al. 1995, Bodzsár et al. 1998, Troiano et al. 1998, Németh et al. 1999, Kuczmarski et al. 2000).

Although the sample size of the present work is not large enough to recommend it as a uniform recent national standard, as a reference it is thought to be suitable for initial scrutiny, e.g. for a comparison of how the two genders develop, but also in considering reports from abroad.

Material and Methods

Data from several regional samples collected by B.É. Bodzsár in the late eighties and early nineties were used. The pooled material contains 8503 children aged between 7 and 19, of whom 5172 were females and 3331 were males. Table 1 shows the distribution by sex and age. Basing on the reports on vital statistics of the Central Bureau of Statistics (KSH 1988, 1989, 1991, 1992, 1993, 1994, 1995) this sample size is about 3 to 7‰ of the respective actual age groups of the two sexes, but it cannot be regarded as nationally representative.

Anthropometry was done conforming to the recommendations of the International Biological Program (Weiner and Lourie 1969). Height was measured by an anthropometer with an accuracy of 1 mm, body mass by a spring balance with an accuracy of 0.5 kg. Distributions were slightly positively skewed for height (minimally skew), weight and BMI (skewness of the same magnitude) for which no explicit adjustment of either the basic or derived measures was made. BMI was computed as kg/m^2.

Table 1. The distribution of the Hungarian child sample by sex and age.

Age (years)	Boys	Girls
7	120	136
8	214	238
9	212	267
10	246	319
11	255	380
12	276	538
13	253	577
14	338	599
15	441	631
16	394	604
17	360	567
18	192	271
19	30	45
Total = 8503	3331	5172

In developing population standards the first step has most often been the construction of a centile distribution of the respective absolute or relative measure, in particular when one has to reckon with important changes with age. In most cases the choice and the number of the centile points is apparently arbitrary though generally retraceable to biological reasons associated with the given attribute. For the present study the decision was to include all the centiles (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th) that have commonly been used in anthropometry. The 85th centile was added to help comparison with the US reference (Kuczmarski et al. 2000).

Despite its well-known limitations (Garn et al. 1986, Ross and Eiben 2002) BMI can serve as an acceptable indicator of nutrition status, because several studies reported its close correlation with adipose tissue mass in adults (Roche et al. 1981, Norgan and Ferro-Luzzi 1982).

The various ways of presenting centile curves was thought worth discussing, because the available Hungarian reports had left this topic methodically untouched. Unsmoothed centile curves of individual BMI values derived directly from stature and weight were termed raw centiles. They are to be shown alongside the centile curves smoothed exponentially and by the so-called LMS method. Smoothing by moving averages often used when dealing with data series subject to considerable random fluctuation was studied as well, but will not be entered upon here since it is associated with an unavoidable loss of data points. In the exponential smoothing employed by us the attenuation coefficient was 0.4 (the function being $x'_1 = x_1$; $x'_i = a \cdot x_i + (1 - a) \cdot x'_{i-1}$ if |i>1, where x is the raw score, x' is the smoothed one, and a is the attenuation coefficient). The LMS method (Cole 1988, 1990, 1995) is used to smooth centile curves by using three parameters. The program developed by Green and Cole for the centile smoothing algorithm provides in addition the best parameters of L, M and S estimated iteratively at the optional number of equivalent degrees of freedom (Cole 1989a, 1989b, Cole, Freeman and Preece 1995). The latter can be utilized for comparisons since the higher the chosen equivalent degree of freedom (edf) the rougher the resulting spline curves. The method is claimed by its developers (Cole 1989b) to efficiently estimate centiles for not normally distributed data by using a Box-Cox power transformation (Box and Cox 1964) changing along age, and even for measuring the skewness of the distribution at a specified age.

The lambda exponent (L) of the power transformation as well as the parameters M (median) and S (coefficient of variation) representing the distribution are age dependent. By using the respective age values of the polynomials fitted to these parameters any centile can be obtained by the LMS formula (Freeman et al. 1995):

$$C_i = M \cdot (1 + L \cdot S \cdot z_i)^{1/L} \; [L \neq 0],$$

where C_i is the centile of interest, and z_i the normal equivalent deviation for this centile. In the present study i, the number of the centiles, was 1 through 10.

The choice of the respective edf for L, M, and S, that is, the maximum rank of the fitted polynomial, is to some extent arbitrary. The extent of the smoothing in the present study was chosen to retain the original tendency of the centile curves in order to allow an analysis of relationships of potential biological significance while avoiding disturbing unevenness. BMI has a variable dispersion during the phase of growth and maturation.

It is noted that the growth charts of the NCHS, USA were downloaded from the web as freely available information so no explicit permission to reproduce them was obtained.

Results and Discussion

Since in respect of the components of BMI the centile distributions are already available (Eiben and Pantó 1986, Eiben et al. 1991; Joubert et al. 2000), we simply present the observed body mass and height means of our sample (Figs. 1 and 2). The distribution of the BMI by age is shown in Table 2.

Table 2. Body mass index values for age in the Hungarian sample.

	Boys					Girls				
Age yr	BMI kg/m^2	SD	SE	Vmin	Vmax	BMI kg/m^2	SD	SE	Vmin	Vmax
7	15.51	2.05	0.19	10.53	23.98	15.61	2.84	0.24	11.12	26.95
8	16.30	2.42	0.17	12.05	27.99	15.51	2.16	0.14	11.42	25.20
9	16.55	2.50	0.17	11.52	25.63	16.05	2.49	0.15	11.05	28.59
10	16.85	2.74	0.17	12.58	29.71	16.66	3.03	0.17	10.81	35.45
11	17.48	3.29	0.21	9.66	32.74	17.28	2.88	0.15	10.57	27.72
12	18.40	3.45	0.21	12.09	29.95	18.21	3.24	0.14	12.66	34.61
13	18.82	3.55	0.22	11.62	34.22	18.72	2.98	0.12	12.53	32.09
14	19.46	3.39	0.18	14.09	37.29	19.39	3.05	0.12	12.72	37.19
15	20.08	3.23	0.15	12.05	35.95	20.50	3.16	0.13	14.56	34.53
16	20.72	3.21	0.16	14.12	35.80	20.71	2.92	0.12	14.67	36.08
17	21.29	2.84	0.15	14.51	39.59	20.66	2.74	0.12	15.72	37.30
18	21.24	2.54	0.18	16.38	34.81	21.03	2.89	0.18	15.83	33.83
19	22.13	2.40	0.40	17.62	28.91	21.23	2.32	0.35	16.17	27.38

Abbreviations: yr: year; SD: standard deviation; SE: standard error of the mean; Vmin: minimum; Vmax: maximum

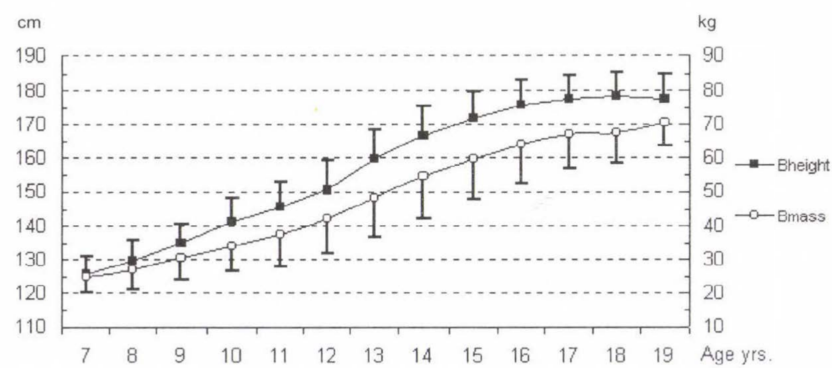

Figure 1: Means and standard deviations of height and weight in the boys.

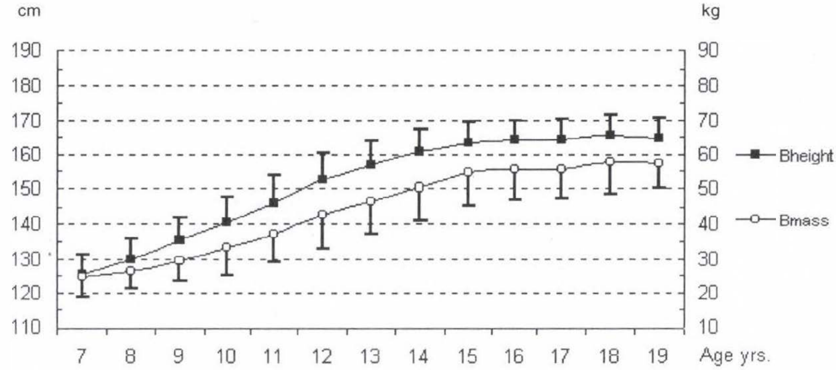

Figure 2: Means and standard deviations of height and weight in the girls.

The BMI averages of this sample mostly showed an increase with age. No significant differences between the genders of the same age were observed. In this regard immediately consecutive groups of age did not differ either.

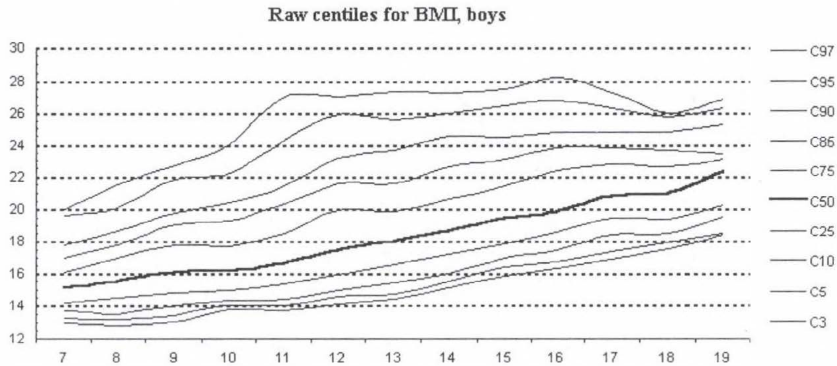

Figure 3: Unsmoothed BMI centiles for the boys. Heavy line: median curve.

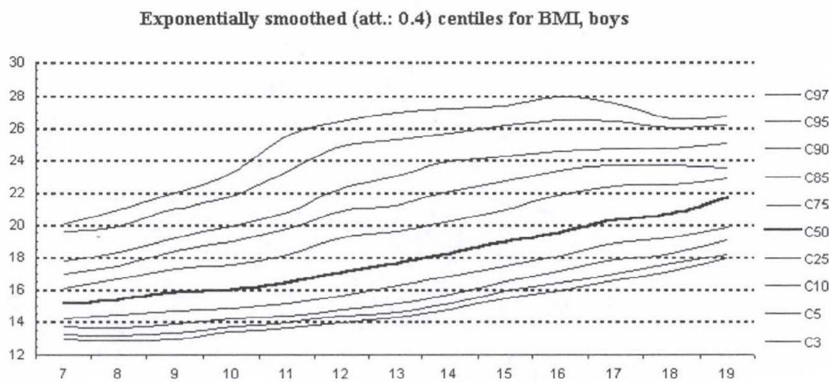

Figure 4: Exponentially smoothed BMI centiles for the boys.

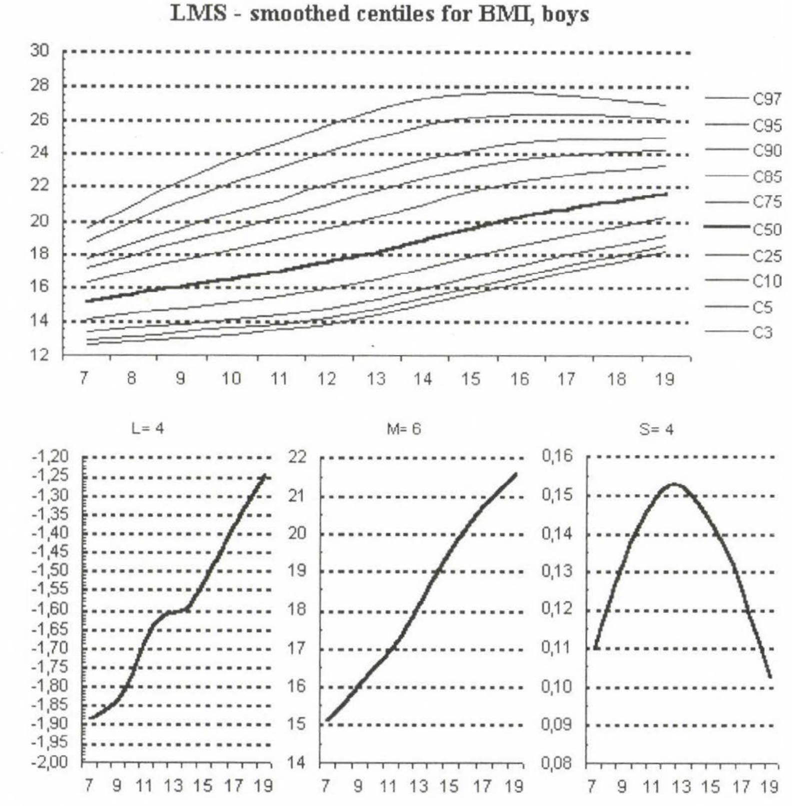

Figure 5: BMI centiles smoothed by the LMS-technique for the boys (top) and the age curves of the LMS parameters of smoothing (bottom). L: lambda power of the Box-Cox transformation; M: median; S: coefficient of variation; numbers after the parameters denote rank of polynomial chosen for parameter estimation.

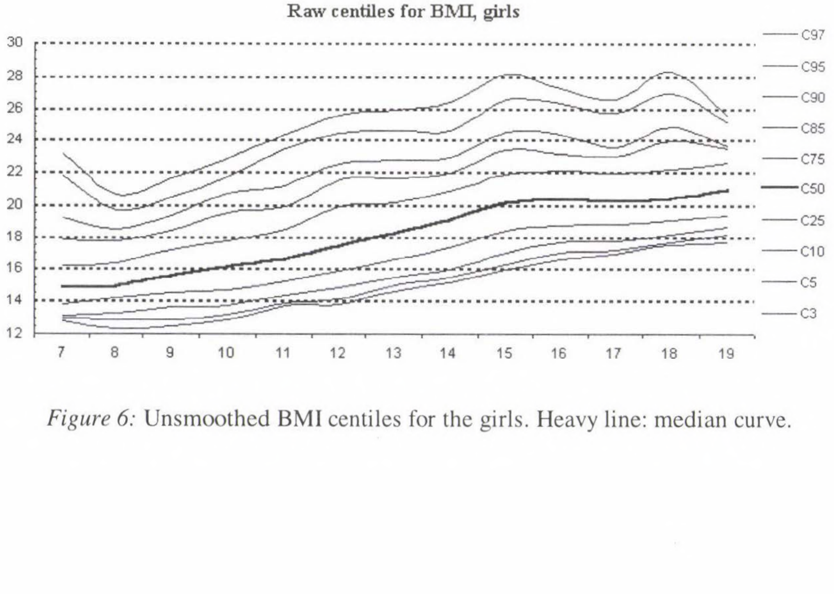

Figure 6: Unsmoothed BMI centiles for the girls. Heavy line: median curve.

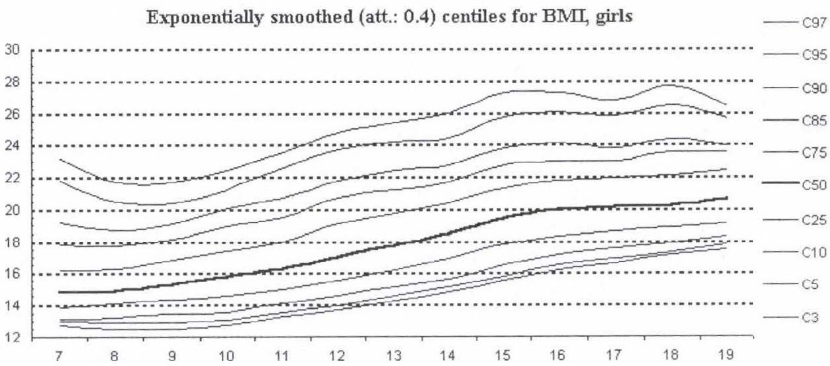

Figure 7: Exponentially smoothed BMI centiles for the girls.

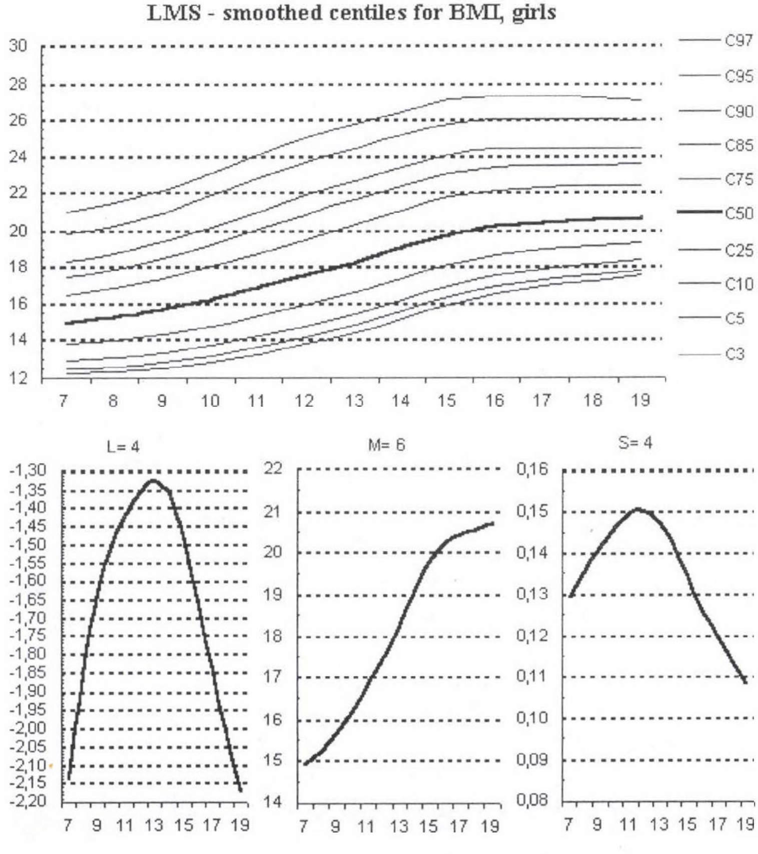

Figure 8: BMI centiles smoothed by the LMS-technique for the girls (top) and the age curves of the LMS parameters of smoothing (bottom). L: lambda power of the Box-Cox transformation; M: median; S: generalized coefficient of variation; numbers after the parameters denote rank of polynomial chosen for parameter estimation.

When the objective is the development of some standard, the knowledge of the centile distribution characteristic of the population is a necessary but not sufficient condition. To classify categories one also needs certain criterion independent from the measure. Centile ranges can then be assigned to these categories when things to be done based on social considerations are decided upon. In dealing with body dimensions such criteria are usually provided by other anthropometric measures.

The raw centiles of BMI for the two genders varied with the years of age. A part of this variation can be explained by biological reasons. So for instance the boys showed a sharper rise of the higher centiles between the age of 10 and 12 (Fig. 3) while the centiles lower than the median maintained their course. In the succeeding phase of life, however, the higher centiles were stable though the ones lower than the median kept growing almost linearly. Individuals in the higher centile ranges (i.e., the heavier ones) can be assumed to have not or not merely developed their fat-free mass but also their adipose tissue reserves. In the subjects of the same centile range mass increment was proportionate to the elongation of stature in the phase of rapid growth. We could assign biological importance also to the observation that the higher the centile range the earlier the slope of the curves rose. It spoke of the tendency of fat accumulation in the early maturers.

Similar traits were not that conspicuous in the raw centiles of the girls (Fig. 6), although there was an obvious levelling off of the centiles higher than the median in the period of faster growth (age 13). Girls belonging to the lowest ranges of centiles were most likely late developers. This assumption may get some support from the observation that the course of the raw centiles became flatter at age 15 for those in the interquartile range whereas for those of the first quartile at age 16 only. In respect of the bonuses of LMS smoothing, biological importance could only be assigned to the age dependent course of the BMI median and coefficient of variation, namely the timing when the median changed its course, and the age when variability was the broadest.

The other part of the fluctuations appeared to be random. Irrespective of which smoothing technique was chosen, intercentile spacing showed that BMI distribution was more or less skewed in both genders: The spacing of the centiles above the median was markedly broader than below it. The L curves for age differed markedly between the sexes: in the boys it showed a steady though not monotonic rise that indicated a gradually decreasing right skew. The age of the sharpest wiggle coincided with that of the peak in the coefficient of variation. In the girls positive skewness was the least marked at the age of 13 with a larger right skewness both before and after that age. We could not explain this difference.

Most of the sets of centile curves reported by others show very little fluctuation which fact strongly suggests that some sort of a posteriori smoothing had been applied although the same was rarely admitted (e.g. third-order polynomial, Joubert et al. 2000; LMS, Rolland-Cachera et al. 1991). In our experience larger differences only appeared between the centile curves smoothed exponentially (Figs. 4 and 7), respectively by the LMS method (Figs. 5 and 8) when tentatively similar low rank polynomials (edf's) were chosen for the iterative estimation of the L, M and S parameters. In these instances the centile curves smoothed by the LMS method showed an almost perfect absence of wiggles. In the transitional phase between prepuberty and puberty – in particular when one considered the overall course of the curves above the median – we observed a spreading proportionate with the variable timing of accelerated growth, then a closing trend when nearing and passing maturity: in this sample the dispersion of BMI was almost 50% less in young adults than between 11 and 13 years of age.

In the developed countries of the world, thus in Hungary too, a considerable fraction of the population is burdened by body weight problems in spite of the complete availability of the pertinent information, the more or less efficient health education and emphasized importance of prevention. Many are already aware of the finding that the children of fat parents far more often have excess weight (Garn et al. 1979, Mueller 1983, Roche 1992), or that overweight children are likely to become fat adults. Reports also refer to the fact that the probability of adult obesity depended on the age at which overweight had become manifest: more than a third of the children who were obese between 3 and 9 years of age, and more than 80% of the children who were obese between 10 and 13 years of age face the increased risk of becoming an obese adult (Wolf et al. 1994). The consistent remeasurement of our children and providing the possible broadest range of people inclusive of the parent communities with the obtained information is therefore of public interest.

The experience gained in this Hungarian sample was worth comparing with studies performed abroad. The data referring to the children of the North American sample (males 2890, females 2960) were collected between 1988 and 1994 (Troiano and Flegal 1998, Kuczmarski et al. 2000). The centiles were smoothed (Figs. 9 and 10).

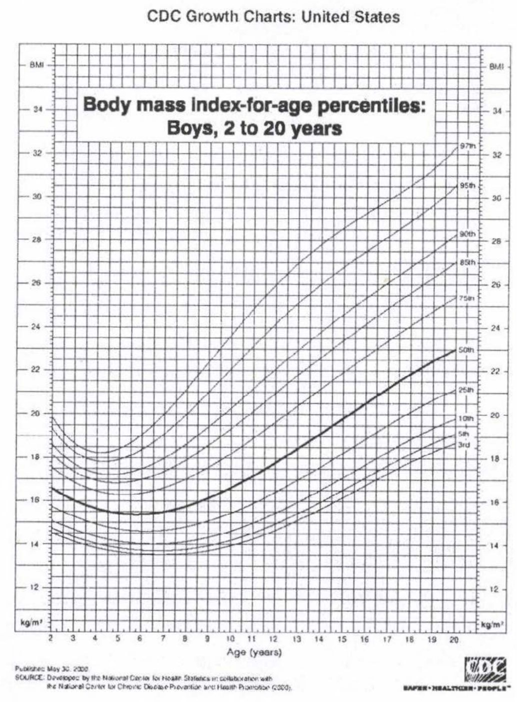

Figure 9: BMI for age chart of the National Health Center, USA, for boys.

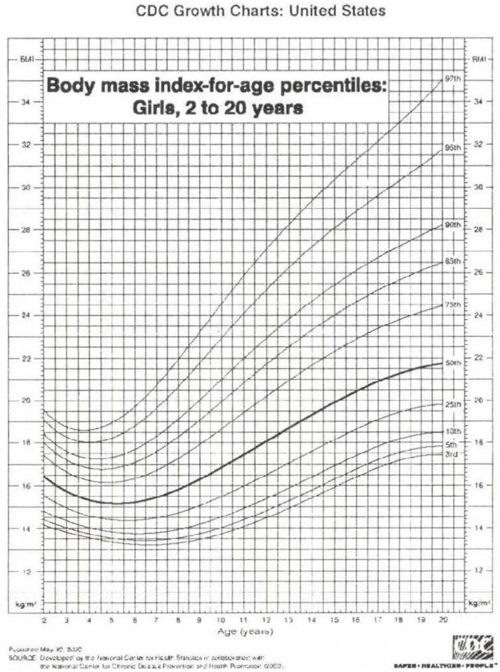

Figure 10: BMI for age chart of the National Health Center, USA, for girls.

The comparison with our sample allowed two statements. In both sexes and at all ages the Hungarian children had lower BMI values. Another difference was seen in the course of the curve set. The curves above the 50th centile showed a slightly steeper rise in both samples. In our sample the centiles for the ages of 18 and 19 neared one another because of the decreasing trend in the curves above the median, despite a monotonic rise of the lower centiles. In the American sample all the curves above the median showed an increasingly steeper slope with some levelling off in the curves at or below the 50th centile. In this way the dispersion of the American sample showed a consistent increase with advancing age while this was not so in our sample.

According to the recommendations of the National Center for Health Statistics (Kuczmarski et al. 2002) children are regarded underweight when their BMI is lower than the 5th centile of the respective age. Their risk of being overweight is associated with a BMI between the 85th and 95th centiles, and above the 95th centile excessive weight is taken for certain. Since the BMI scores for the 5th, 85th and 95th centiles are less in the Hungarian children than the US norms, an American child of the same age, sex and BMI would „qualify" as overweight in Hungary. Conversely, since in our sample the 97th centiles of the age categories fail to reach the 85th centile of the American standards, with some exaggeration one might deduce that there are no overweight children in our country, a statement in sharp contrast with everyone's experience.

The differences between the two samples may have arisen for a multitude of reasons. The dissimilarities could be retraced either to genetic causes or to effects attributable to environmental differences. We have no objective ground for speculations about causal factors so we do not dare to enter into details. However, we have to be aware of the differences in constructing the centile sets. As shown by our experience, the greater the extent of smoothing the more depressed the curve set becomes. Since despite their smaller sample size the American curves were smoother than ours, it is quite likely that the original raw centiles had belonged to higher BMI values. The contrast with our sample is thus even more conspicuous. This observation definitely discourages the application of norms belonging to another population, although previously this had been fairly common in Hungarian child care.

Summary Conclusions

The purpose of the present study was to carry out a pilot study which could contribute to the assessment of the nutrition status of school-age children and to provide information on it to parents and people interested in public health. To achieve this goal the development of a Hungarian centile distribution of the BMI was necessary, this index being broadly used for assessing nutrition status. Centiles are used as a basis for standards and, when associated with the classification categories of some external criterion, may serve for screening and diagnosis. A point of great importance is that only standards valid for the population studied should be used. The distribution of the measure, in this case the body mass index, is subject to changes with time under the effect of genetic and environmental factors. This fact necessitates consistently repeated revisions of any norm. In elaborating cut off values that show acceptable validity in respect of other indicators of physical development one should allow for other approaches. Above all, also cut offs have to be population specific while following a logic presumably valid for other populations. Cut offs expressed as centile limits do not serve comparability well so one should consider the biological background instead, in particular for BMI. The preliminary data supplied here are not yet standards, only a sort of reference helping the assessment of the child under study and directing attention to the trends becoming manifest with advancing age. The authors hope that the relevant data base may grow, and soon provide an opportunity to construct a valid and representative centile distribution of the body mass index of children. Then hopefully also the category cut offs can be defined as the second step of developing norms. In that process there is a promise of learning about possible secular changes in this respect as well. Raw centiles are likely to contain more biological information while smoothed centiles perhaps approximate population values better so allowing comparative analyses.

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