USING OF ANTHROPOLOGICAL METHODS IN EVALUTION OF CHILDHOOD OVERWEIGHT AND OBESITY

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Abstract: *The problem of childhood obesity is at present of major interest. Obesity is characterized above all by excessive body weight associated with cumulating of body fat. This is associated with cumulating of risk factors some of with are manifested already in childhood. The prevalence of obesity is increasing steadily in advanced countries as well as some developing countries. This trend is manifested the cause is in the imbalance between the energy intake and energy output, however, relationships only respective. Obesity is multifactorial disease. The simplest manner of defining obesity is provided by selected methods of clinical anthropology, e.g. using of Matiegka´s formulas. This method analysed body composition, is non-invasive, easy to use in the field, suitable for short-time examination of patients and relatively cheap.*

Key words: overweight, obesity, anthropological methods, BMI, Matiegka´s eguations.

1 Introduction

Obesitology is a branch of medicine that provides a wide field of application for methods of clinical examination under the overall heading of physical anthropology. Its scope of study is represented by harmful and excessive overweight, which is regarded as one of the most severe disorders troubling modern civilisation in developed industrial countries. In the past decade its occurrence has risen dramatically in most western societies, making it an alarming and predominant phenomenon as early as at the first stages of childhood. Its expansion is conditioned primarily by the social and economic status of human populations, especially by their lifestyle and standard of living. However, it depends chiefly on a number of individual factors, on a person's specific disposition, on the body build and genetic inheritance. Last but not least, family upbringing and schooling play a significant role.

A typical trait of obese individuals is seen in an abnormal body build showing a remarkable predominance of excessive fat development. The quantification and qualification of obesity (in the sense of distribution of subcutaneous fat in the body) poses a difficult problem to tackle by scientific research. Its difficulty is not lessened by the wide scale of theoretical methods applied. An obese subpopulation represents a serious problem for all age groups, because the ontogenetic development of obese individuals diverges from the normal population as early as the first stages of childhood.

The simplest manner of defining obesity is provided by selected methods of clinical anthropometry. In combination with biochemical methods and other procedures of clinical examination, they enable us to detect the precise somatic composition of an obese individual. They make it possible to control his biochemical status, propose a convenient reduction diet and check the success of treatment on his figure. The main advantage of anthropometrical methods is their non-invasive character. They are not time-consuming, expensive or extremely demanding. Since they rely mostly on clinical examination, they do not require extensive field research.

In estimating and monitoring the somatic habitus of an obese individual as well as in evaluating the success of reduction diet, it is beneficial to choose anthropometrical measurements that do not require the presence of a professional anthropologist. Such routine measurements adhere to simple characteristics such as the BMI index, selected girth parameters and skinfold thickness measured by a Best or possibly Harpenden caliper. Such elementary examination may be completed by measurements requiring a qualified anthropologist’s attendance in interpreting data obtained. They establish proportions for determining components of the somatic composition of a body according to Matiegka’s equations, selected indices of body mass, indices of centrality and others.

Nearly 80 years ago, the Czechoslovak anthropologist Jindřich Matiegka proposed a method for the anthropometric fractionation of body mass into four main components: skeletal mass, fat mass, muscle mass, and residual or vital organ/visceral mass. He was a kinanthropometrist concerned with determining the physical efficiency of an individual. He was interested in particular in the estimation of muscular strength from anthropometric estimates of body mass. A few investigators, such as Pařízková, acknowledged their debt to Matiegka, but many other investigators working in the field of body composition appear to have overlooked his insightful work.

2 Aim

Evaluation of the degree of obesity in children by means of anthropometric methods has many variants. The variants differ as to the degree of differentation of different body constituents and thus also the number of parameters included in the list.

3 Methods descriptions

Possible anthropological assessment of obesity in children:

A. ***BMI – In the child and adolescent population the usual categories of BMI*** (e. g. according to Knight) cannot be used. However, we are faced increasingly with the necessity of categorization in the child and adolescent population. For the obese Czech child and adolescent sub-population classification of obesity grades was lacking. Therefore values of the 3rd, 25th, 50th, 75th, 90th and 97th empirical BMI percentile of the obese subpopulation were calculated for age groups from 6 to 18 years, separately for each sex. This enabled us to define three grades of obesity by BMI in relation to sex and age. As liminal values of BMI defining the lower borderline of grade 1 we took values of the 97th percentile of different age groups of the Czech reference population (5th Nationwide Anthropological Survey in 1991). The upper borderline of the first grade of obesity are values of the 50th percentile of the sub-population of the investigated group of obese subjects (8237 probands). The second group comprises subjects with BMI values between the 50th and 90th percentile of the investigated obese sub-population. The third grade of obesity comprises probands with BMI values above the 90th percentile. We wish to present therefore to the professional public for practical use a table 3 ***„Limit BMI values defining values of 3 grades of obesity in the Czech child and adolescent population“***.

B. ***BMI differentiated into two components: body fat and lean body mass***

However, the BMI is not sufficient for the evaluation of the degree of obesity and its changes during reducing treatment. Attempts to solve the dependence of BMI on height by some compromise cannot be rejected but the body fat and lean body mass component should be considered separately in a given index.

$$\text{BMI} = \frac{W}{H^2} = \frac{F}{H^2} + \frac{LBM}{H^2}$$

W – Body weight in kilograms

H – Body height in metres

F – Body fat mass in kilograms

LBM – lean body mass in kilograms.

C. ***Matiegka´s formulas for estimation of body components***

$W = O + D + M + R$

W – Body weight in gramsO – Skeletal mass in grams

D – Mass of the skin and subcutaneous adipose tissue in grams

M – Muscle mass in grams

R – Residual mass in grams

SKELETAL MASS – O

$O = o^2 \cdot H \cdot k_1 \qquad o = \frac{o_1 + o_2 + o_3 + o_4}{4}$

o_1 – width of the distal humeral epiphysis

o_2 – width of the wrist

o_3 – width of the distal femoral epiphysis

o_4 – width of the ankle

H – body height

k_1 – 1.2

All measurements are in centimetres.

MASS OF THE SKIN AND SUBCUTANEOUS ADIPOSE TISSUE – D

$D = d \cdot S \cdot k_2 \qquad S = 71.84 \cdot W^{0.425} \cdot H^{0.725}$

$$d = \frac{1}{2} \cdot \frac{d_1 + d_2 + d_3 + d_4 + d_5 + d_6}{6}$$

d – Sum of skinfolds in centimetres

d_1 – upper arm skinfold above biceps

d_2 – anterior side of the forearm at maximum breadth skinfold

d_3 – thigh above the quadriceps muscle halfway between the inguinal fold and the knee

d_4 – calf (medial)

d_5 – thorax at the costal margin halfway between the nipples and the navel (chest 2)

d_6 – on the abdomen in the upper third of distance between the navel and the superior anterior iliac spine

S – Body surface area in square centimetres (3); can be assessed by means of a nomogram (figure I. 5. – 1)

W – Body weight in kilograms

H – Height in centimetres

k_2 – 0.13

Skinfold thickness in centimetres. MUSCLE MASS – M

$$M = r^2 \cdot H \cdot k_3 \qquad r = \frac{r_1 + r_2 + r_3 + r_4}{4}$$

r – Representing the radii calculated from circumferences in centimetres

H – Body height in centimetres

k_3 – 6.5

The circumferences must be corrected for the thickness of the subcutaneous tissue + skin (fat).

Formula for computing of radius (r_x) of circumferences (Cr_x) corrected for fat:

$$r_x = \frac{Cr_x - 3.1416 \cdot \text{skinfold}}{2 \cdot 3.1416}$$

Cr_1 – circumference of the relaxed arm in centimetres

Cr_2 – maximum circumference of the forearm in centimetres

Cr_3 – median circumference of the thigh in centimetres

Cr_4 – maximum circumference of the calf in centimetres

RESIDUAL MASS – R

$$R_1 = b \cdot H \cdot k_4 \qquad b = \frac{b_1 + b_2 + b_3}{6} + \frac{b_4}{2}$$

$R_2 = W - (O + D + M)$ $R_{Matiegka} = W \cdot 0.206$

R – Eligible:

R_1 – residual calculated in grams

R_2 – mass of the remainder in grams (residual supplemented)

$R_{Matiegka}$ – residual calculated according to Matiegka (5)

H – Body height

k_4 – 0.34

b_1 – biacromial width

b_2 – bicristal width

b_3 – transverse diameter of the chest

b_4 – sagittal diameter of the chest

W – Body weight in grams

O – Skeleton mass in grams

D – Skin and subcutaneous adipose tissue mass in grams

M – Muscle mass in grams

All measurements are in centimetres.

For practical application of Matiegka´s equations see table 4.

4 Discussion

Applications of anthropometrical methods in obesitology may be summarised in the following items:

(1) The advantage of classical anthropometrical methods is their non-invasive character; most of them are relatively cheap without requiring extensive field research and time-consuming activities.

(2) The ontogenetic development of obese individuals diverges from normal populations as early as the first stages of childhood. It involves all somatic characteristics manifested in the acceleration of growth in childhood and excessive development of body mass (Tables 1, 2).

3. In order to attain higher objectivity, it is beneficial to make use of the BMI index:

(a) In children and adolescents the values of the BMI index vary significantly with age, and therefore it is not permissible to apply to children populations methods of classification elaborated and standardized for adult populations (e.g. methods devised by Knight);

(b) We recommend using the percentile graph BMI (Part 4.3 -Figure 1a, Figure 1b): 90th – 97th percentile BMI – excessive body mass, BMI over 97th percentile – obesity;

(c) Degrees of obesity in obese individuals at the age of 6 to 19 may be determined according to the table ‘Limit values of the BMI index defining 3 degrees of obesity in the Czech population of children and adolescents’ (Table 3);

(d) If we have at our disposal information about fat component, we should divide the BMI index into the fat component and the component of ‘fat-free body masses.

(4) The WHR index provides limited information on degrees of obesity; in the latest literature it is recommended to evaluate girth parameters separately.

(5) The component of fat in the somatic composition is estimated as follows:

(a) In order to estimate the total amount of the fat component by measuring skinfold thickness, in common practice it is recommendable to use calipers;

(b) It is common to use calipers of the BEST or HARPENDEN brand (different pressure, different sizes of surface); it is not permissible to use values obtained by one type of caliper for calculating values obtained by another caliper; transformation of values between two different types of calipers is carried out by means of conversion tables;

(c) The BEST caliper is more suitable for measuring skinfold thickness in obese individuals, because it covers a considerably wider range of values;

(d) Owing to uneven distribution of fat in various parts of the body it is convenient to apply the method that includes more skinfolds into calculation; usually is used examination according to Matiegka’s equations, adult populations may also be examined with the aid of Pařízková’s regressive equations.

(e) Bioelectrical impedance may be used only if we observe the regime of examination strictly. Its use for obese populations of children is controversial. If there is no convenient software, it is not appropriate to use it for populations of sportsmen and for normosthenic populations of children either.

(6) Indices of centrality give a precise approximation of the distribution of subcutaneous fat.

(7) Matiegka’s equations provide an efficient tool for a more detailed analysis of body fat composition on the basis of measurements of given parameters.

(8) The success of treatment by reduction diets aiming to reduce the amount of body fat may be evaluated according to the decrease in selected girth parameters and skinfold

thickness, providing we respect the hierarchy of their mutual importance. More detailed subsequent evaluations may observe differences in body fat composition determined according to Matiegka's equations. The decrease of the body fat component should exceed seven times the decrease of muscular mass.

5 Conclusions

We have proved Matiegka's equestions like usefulness both theoretically and for practice. Why to use Matiegka's equestions? They are based on European populations. The method is non-invasive, easy to use in the field, suitable for short-time examination of patients and relatively cheap.

We recommend using Matiegka´s equations for evaluation of reduction of body mass, as they are based on easily measured anthropometric parameters, which enable us to specify the mass of skeleton, muscles, fat and residual tissues. The methods are suitable for rapid examination of probands and relatively cheap.

As for the Body Mass Index, we recommend to differentiate between the fat component and lean body mass.

6 References

Bláha P., et al. (1990) *Antropometrie českých předškolních dětí ve věku od 3 do 7 let, díl 1. a 2. (Anthropometry of Czech preschool children aged 3 – 7 years, part 1 and 2).* Praha: ÚSM.

Bláha P., Vignerová J. at. al.(2002) *Ingestivation of the growth of Czech children and Adolescents.* Praha, SZÚ; PřF UK.

Bláha P., Krejčovský L., at. al. (2006) *Somatický vývoj současných českých dět; semilongitudinální studie (Somatic development of contemporatory Czech children; Semilongitudinal study)* Praha PřF UK, SZÚ.

Drinkwater, D. T., Ross W. D. (1980) Anthropometric fractionation of body mass. *In: Kin-anthropometry II*. Baltimore: University Park Press, pp. 178 – 189.

Fetter V. et al. (1967) *Antropologie. (Anthropology)*. Praha: Academia.

Lhotská L., Bláha P., Vignerová J., Roth Z., Prokopec M. (1993) *V. Celostátní antropologický výzkum dětí a mládeže 1991 (České země), Antropometrické charakteristiky. (5th Nationwide Anthropological Survey of Children and Adolescents 1991 (Czech regions), Anthropometric characterstics).* Praha: SZÚ.

Matiegka J. (1921) The testing of physical efficiency. *Am. J. Phys. Anthropology*. 4: 223 – 230.

Vignerová L., Riedlová J., Bláha P., Kobzová J., Krejčovský L., Brabec M., Hrušková M. (20006) *6. Celostátní antropologický výzkum dětí a mládeže 2001 (Česká republika) (6 th Nation-wide Anthropological Survey odf Children and Adolescents 2001, Czech Republic),* Praha, PřF UK; SZU.

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8 Appendix

Nomogram for determination of body surface from height and weight

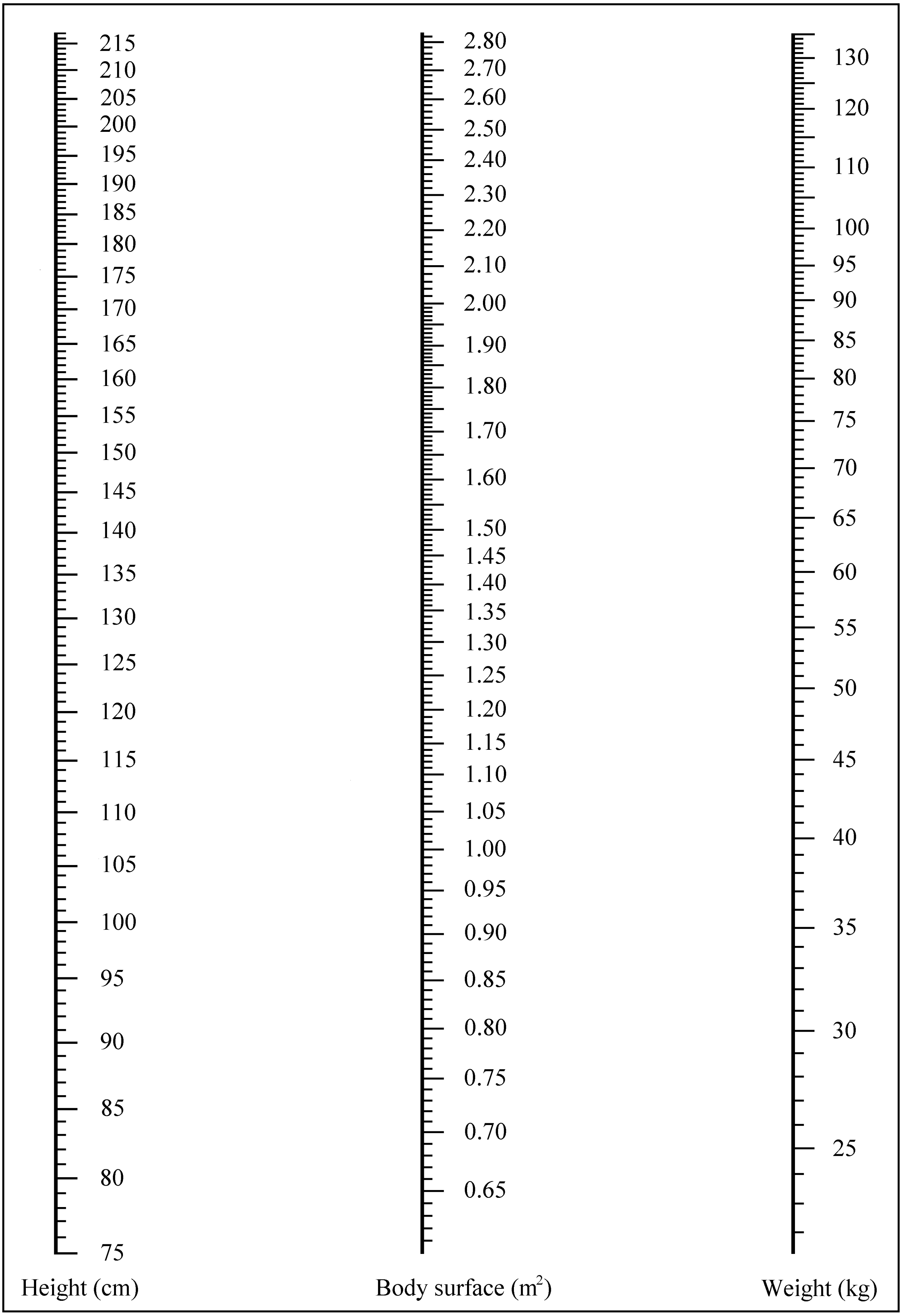

Table 1 *Basic body parameters*
(sample of Czech obese children) Boys (n = 3039)

BOYS		Body height (cm)			Body weight (kg)			BMI (kg/m^2)		
Age/ years	n	$\bar{x}$	s. d.	Z-score	$\bar{x}$	s. d.	Z-score	$\bar{x}$	s. d	Z-score
6.00 – 7.99	88	127.7	9.63	**0.71**	41.8	8.10	**4.61**	25.7	3.00	**5.64**
8.00 – 8.99	99	137.8	6.32	**1.01**	49.6	8.42	**4.54**	26.0	3.41	**4.85**
9.00 – 9.99	198	143.6	6.20	**1.06**	54.9	9.73	**4.15**	26.4	3.72	**4.24**
10.00 – 10.99	347	148.5	6.90	**0.81**	59.3	10.05	**3.70**	26.8	3.15	**3.64**
11.00 – 11.99	529	153.6	7.06	**0.73**	65.0	11.12	**3.36**	27.5	3.46	**3.59**
12.00 – 12.99	600	157.8	7.87	**0.57**	69.8	12.16	**3.51**	28.0	3.63	**3.50**
13.00 – 13.99	626	163.7	8.14	**0.31**	77.5	12.43	**3.01**	28.9	3.73	**3.57**
14.00 – 14.99	326	168.0	8.17	**0.03**	84.8	15.55	**2.78**	29.9	4.32	**3.90**
15.00 – 15.99	95	171.6	7.74	**- 0.15**	91.6	19.02	**3.61**	31.6	5.16	**4.42**
16.00 – 18.99	131	177.6	8.44	**0.15**	105.6	19.23	**3.90**	33.2	4.61	**4.32**

Table 2 *Basic body parameters*
(sample of Czech obese children) Girls (n = 5198)

GIRLS		Body height (cm)			Body weight (kg)			BMI (kg/m2)		
Age/ years	n	$\bar{x}$	s. d.	Z-score	$\bar{x}$	s. d.	Z-score	$\bar{x}$	s. d	Z-score
6.00 – 7.99	175	129.1	7.51	0.97	41.0	8.07	4.33	24.6	3.47	4.94
8.00 – 8.99	172	138.4	7.62	1.05	48.1	9.56	4.23	24.9	3.57	3.83
9.00 – 9.99	330	142.4	6.75	0.82	52.4	8.95	3.36	25.6	3.00	3.63
10.00 –	457	148.3	7.05	0.74	57.3	9.83	3.41	26.0	3.25	3.44
11.00 –	744	153.6	7.04	0.48	63.6	11.22	2.93	26.9	3.56	3.41
12.00 –	785	158.7	6.40	0.38	71.3	11.61	3.24	28.2	3.73	3.32
13.00 –	102	161.9	6.44	0.32	77.2	12.14	3.62	29.3	3.84	3.47
14.00 –	812	163.7	6.80	0.22	80.3	13.21	3.70	30.2	4.52	4.07
15.00 –	294	164.2	6.80	0.17	81.8	14.16	4.16	30.4	4.11	4.16
16.00 –	401	165.0	6.50	0.02	85.6	15.20	4.05	31.6	4.76	4.04

Z-score calculated in relation to reference values of normal child population of corresponding age groups (Bláha et al. 1986, Lhotská et al. 1993)

Table 3 *Limit BMI values of 3 grades of obesity in the Czech child and adolescent population*

Age/ years	BOYS			GIRLS		
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
	Mild obesity	Medium obesity	Severe obesity	Mild obesity	Medium obesity	Severe obesity
6.00 – 6.99	19.6 – 24.8	24.9 – 28.8	> 28.8	19.7 – 24.8	24.9 – 28.6	> 28.6
7.00 – 7.99	20.2 – 25.0	25.1 – 29.2	> 29.2	20.6 – 24.6	24.7 – 28.8	> 28.8
8.00 – 8.99	21.1 – 25.3	25.4 – 30.4	> 30.4	21.5 – 24.4	24.5 – 28.8	> 28.8
9.00 – 9.99	22.2 – 25.7	25.8 – 30.5	> 30.5	22.4 – 25.2	25.3 – 29.4	> 29.4
10.00 –	23.3 – 26.2	26.3 – 30.9	> 30.9	23.1 – 25.7	25.8 – 30.0	> 30.0
11.00 –	24.3 – 27.0	27.1 – 32.0	> 32.0	24.2 – 26.3	26.4 – 31.4	> 31.4
12.00 –	24.8 – 27.8	27.9 – 33.3	> 33.3	25.3 – 27.6	27.7 – 32.8	> 32.8
13.00 –	25.1 – 28.6	28.7 – 33.5	> 33.5	25.6 – 28.9	29.0 – 34.6	> 34.6
14.00 –	25.5 – 29.3	29.4 – 34.7	> 34.7	25.5 – 29.5	29.6 – 35.0	> 35.0
15.00 –	26.2 – 31.0	31.1 – 39.6	> 39.6	25.8 – 29.7	29.8 – 36.3	> 36.3
16.00 –	26.9 – 32.5	32.6 – 38.3	> 38.3	27.2 – 30.2	30.3 – 37.3	> 37.3
17.00 –	27.6 – 33.5	33.6 – 40.4	> 40.4	27.3 – 31.4	31.5 – 38.1	> 38.1

The table was elaborated on the basis of the reference group of 8237 obese Czech children and on data from the 5th Nationwide Anthropological Survey 1991. © Bláha P. 2001

Table 4 *Other investigated parameters*
Selected parameters listed according to paired t-test
Czech obese children (6 – 16 years)

Parameter	BOYS			GIRLS		
	Paired t-test		Difference	Paired t-test		Difference
	n =	n =		n =	n =	
Weight	56.54	23.70	- 8.67 kg	70.80	22.72	- 7.60 kg
Calculated weight	40.04	19.44	- 7.79 kg	48.87	18.63	- 6.95 kg
Muscles (Matiegka) – kg	9.24	3.89	- 0.82 kg	6.87	2.21	- 0.45 kg
Muscles (Matiegka) – %	28.62	12.02	+ 3.66 %	37.94	12.21	+ 3.54 %
Fat (Matiegka) – kg	55.35	23.27	- 7.79 kg	68.11	21.90	- 6.56 kg
Fat (Matiegka) – %	50.47	21.21	- 6.94 %	58.66	18.87	- 6.32 %
Sum of 10 skinfolds	64.32	29.92	- 56.80 mm	68.60	24.72	- 49.20 mm
% of fat (Pařízková)	45.34	19.69	- 3.43 %	68.60	22.22	- 4.76 %
BMI	71.58	30.00	- 3.56	86.31	27.70	- 3.21
Rohrer index	66.64	27.94	- 0.23	76.68	24.61	- 0.21
Ponderal index	71.64	30.03	+ 1.80	78.88	25.31	+ 1.61
WHR index	15.81	6.23	- 2.37	14.63	4.71	- 2.30

Conversion table of skinfold thickness values assessed by a best caliperto tovalues of a Harpenden caliper

The skinfold thickness assessed for estimation of the body fat percentage is measured by a Best caliper or Harpenden caliper. These calipers differ above all by their shape of contact surfaces and also by a different pressure. For calculation of body fat on the basis of skinfold thickness a number of re-egression equations or tables are used which were designed for a specific type of caliper. Therefore it is not permissible to assess the body fat from values measured by a Best caliper according to equations or tables for a Harpenden caliper and vice versa. As the majority of departments possess only one type of caliper, we prepared a conversion table (table I. 6. – 1).

The percentile thicknesses of selected skinfolds, which are presented in chapter I. 4. were measured by means of a Harpenden caliper. The mentioned table thus makes it possible to convert values assessed by a Best caliper to values of a Harpenden caliper. Every skinfold behaves differently in relation to the caliper, therefore conversion values are given separately for each skinfold.

The submitted table is the result of regression analysis, which was implemented on the basis of parallel measurements of selected skinfolds by both types of calipers. In this way 2898 probands were examined (1363 boys and 1535 girls) aged 3 to 18 years. Analysis revealed that skinfolds measured by both types of calipers behave similarly in boys and girls (correlation coefficient r = 0.98). Thus the table makes it possible to convert values regardless of gender.

Example of use:

Using a Best caliper for the skinfold above the biceps a 10 mm value was assessed. In column I of table 5. – 1 we look up value 10. In this line in column 2 (biceps) we find value 10.4. The latter value corresponds to the value we would obtain by measuring the skinfold above the biceps by a Harpenden caliper. The table can be used also for conversion of values obtained by a Harpenden caliper to values of a Best caliper.

Table 5 *Conversion of skinfold thickness values assessed by a Best caliper to values of a Harpenden calliper*

Values measured by a Best caliper	Biceps	Triceps	Suprailiacae	Subscapulare	Frontal thigh
1	2	3	4	5	6
1	2.2	-	2.2	-	-
2	3.2	3.4	3.1	3.2	4.4
3	4.0	4.4	4.2	4.2	5.6
4	4.8	5.4	5.2	5.2	6.6
5	5.8	6.4	6.2	6.2	6.4
6	6.8	7.2	7.2	7.2	7.4
7	7.6	8.2	8.2	8.2	8.6
8	8.4	9.2	9.4	9.2	9.6
9	9.4	10.2	10.2	10.2	10.6
10	10.4	11.2	11.2	11.2	11.6
11	11.2	12.0	12.2	12.2	12.6
12	12.2	13.0	13.4	13.2	13.6
13	13.0	14.0	14.4	14.2	14.6
14	14.0	15.0	15.4	15.2	15.6
15	14.8	16.0	16.4	16.2	16.6
16	15.8	17.0	17.4	17.2	17.6
17	16.6	17.8	18.4	18.2	18.6
18	17.6	18.8	19.4	19.2	19.6
19	18.4	19.8	20.4	20.2	20.6
20	19.4	20.8	21.6	21.2	21.6
21	20.2	21.8	22.6	22.2	22.6
22	21.2	22.8	23.6	23.2	23.6
23	22.4	23.6	24.6	24.2	24.6
24	23.2	24.6	25.6	25.2	25.6
25	24.2	25.6	26.6	26.2	26.6
26	25.2	26.6	27.6	27.2	27.6
27	26.2	27.6	28.6	28.2	28.6
28	27.2	28.6	29.6	29.2	29.6
29	28.2	29.4	30.8	30.2	30.6
30	29.2	30.2	31.8	31.2	31.6
31	30.2	31.2	32.8	32.4	32.6
32	31.2	32.4	33.8	33.4	33.6
33	32.2	33.4	34.8	34.4	34.6
34	33.2	34.4	35.8	35.4	35.6
35	34.2	35.4	36.8	36.4	36.6
36	35.2	36.4	37.8	37.4	37.6
37	36.2	37.4	38.8	38.4	38.6
38	37.2	38.4	39.8	39.4	39.6
39	38.2	39.4	40.8	40.4	40.6
40	39.2	40.4	41.8	41.4	41.6