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COMPONENTS OF BODY MASS AND THEIR RELATIONS DURING THE GROWTH PERIOD OF THE BOYS

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ABSTRACT. In the present work we study the development and variability of body mass components and their relation during the growth period of the boys. The sample included 513 boys from town of Smolyan (Bulgaria) measured in 1998-2001 and aged 7-17. By means of Martin-Saler's (1957) method of each person two total body measurements, four circumferences, four epicondylar diameters of the lower and upper limbs were measured. For characteristics of the fat development of each person by means of GPM caliper with constant pressure of $10g/mm^2$ eight skinfolds were measured. Using formula body mass index (BMI, kg/m^2) was calculated. The all observed persons have normal physical development and body nutritional status (not-overweight and not-obesity). The nutritional status was defined using the International cut -off points of BMI, created by Cole et al. (2000). The development of the body mass components was based on anthropometric assessment of the fat, muscular, bone and residual mass. They were calculated using Matiegka (by Векслер, 1988) and Mc Ardle, Katch and Katch (1986) formulas. The data were processed implementing descriptive and correlation analysis.

The results of following analysis show that the total body mass growth during the childhood have been different importance, structure and mechanism. It's base are the qualitative changes in body composition, wich occur at certain stages of boys development and characterized with different relation between the fractions, constituting body mass. Body mass changes of the boys with normal physical development and nutritional status are associated to a significantly higher degree with changes in muscle and bone tissues mass, than with fat tissue mass changes, which results can be used for diagnostics of overweight and obesity during growth period.

KEY WORDS. body mass components; fat, bone, muscle, residual mass; growth, development, boys.

INTRODUCTION

Auxological studies of the progressive stages of ontogenesis are of great interest to the scientist mainly because of the opportunity to carry out optimal monitoring of growth processes and deviations diagnostics physical development. Total body signs-such as height, weight and chest measurement are most frequently used to evaluate child physical development. Basic importance is attributed to the values of height and weight since on the basic of these indexes and their relation evaluation charts of physical development are being created. Lately those evaluation charts are applied to assess the developmental status and nutritional evaluation for children and adults (Rolland-Cachera, M., 1998; WHO, 1995; 1997; Cole et al., 2000, Armstrong, J., 2003 and other).

However the individual's developmental status and nutritional evaluation cannot be estimated synonymously with the help of these relations only, because providing a general idea of the total body mass quantitative changes, they do not provide explanation at what expenses those changes are carried out (Чтецов, 1970).

The relation between body mass components is different during the different stage of growth (Häger et all., 1977; Prader, Largo, Molinari, Issler, 1989; Deurenberg, Pieters, Hautvast,1990; Ramirez, 1993; Rico et al., 1993; Haschke, 1989; Ogle et al. 1995; Molgaard, Fleischer Michaelsen,1998; Векслер, А, 1988; Година, 2001; Nikolova, Mladenova, 2004; Гурбо, 2005 and other) and under the some influences (Cowell et al., 1997; Задорожная, 1998; Jaquet et al., 1999; Година, 2001; Arfai et al., 2002 and other). In this connection for the correct development evaluation requires approaches the methods and techniques revealing the organism's qualitative changes which occur at certain stages of it's development and he at the basis of the mature organism formation. Similar approaches are associated with investigation of body composition (Чтецов, 1970; Frisancho, A.,1984; Векслер; 1988; Rolland-Cachera, 1993; Rolland-Cachera et al., 1997; Bolzant,A., Guimarey,L., Frisancho, A.1999; Nikolova, Mladenova, 2004 and other) i.e. relation between components, constituting the body mass. The application of these methods showed that the children with similar weight or overweight have been different quantity and relation of the basic body mass components- bone, fat and muscle tissue mass and will be have different evaluation of their physical development and nutritional status.

In this contex the **aim** of our research is to study the development and variability of the body mass components and their relation during the growth period of the Smolyan boys (Bulgaria).

MATERIAL AND METHODS

Anthropometrical examination of 513 boys within age range of 7-17 years from town of Smolyan, were carried out in the period 1998-2001.

By means of Martin-Saler's (1957) method on each person two total body measurements – height (H,cm) and weight (W,kg), four circumferences – upper arm, forearm, thight and calf circumferences (cm), four epicondylar diameters of the lower and upper limbs – of the elbow, wrist, knee and ankle (cm) were measured.

For the characteristics of the fat development were measured eight skinfolds – the triceps, biceps, forearm, thigh, calf, subscapular, abdomen and the suprailiac (mm). The skinfolds were measured by means of GPM caliper with constant pressure of $10 g/mm^2$. Using the formula body mass index (BMI, kg/m^2) was calculated.

The all observed persons have normal physical development and body nutritional status (not-overweight and not-obesity). The nutritional status was defined using the International cut -off points of BMI, created by Cole et al. (2 000).

The development of the body mass components was based on anthropometric assessment of the fat, muscle, bone and residual mass used the Matiegka's method (by Векслер, 1988). The bone, muscle and residual mass through Matiegka's formulae were calculated. The body fat mass was calculated on the base of the body fat, calculated by Mc Ardle, Katch and Katch (1986) formulae.

The data were processed implementing descriptive and correlation analysis.

RESULTS AND DISCUSSION

The results of our research show that the absolute values of examined components (fig.1) increase parallel with the values of the body mass throughout the investigated growth period. As can be seen from the figure the muscle mass increase significantly ($p<0.05$) during the entire period, as for the same period it growth is 18.83 kg. The mass of residual component, which constitutes in the body fluids mass, minerals and other organic substances increase irregularity from 6.44 kg to 10.67 kg at the end of the period, while the bone tissue mass increase with 7.85 kg for all observed period. The maximum increase of the bone mass is between the 9-10th, 12-13th and 16-17th years of age ($p<0.05$). The growth of the fat component is total 4.68 kg, as the it's maximum increase ($p<0.05$) can be observed between 10-11th (1.29 kg) and 14-15th (1.28 kg) years of age. Finding in previous studies (Асенкевич, 2002 and other) showed pre-pubertal growth jump of the fat contents of both sexes, which decrease in time of the puberty period under influence of the intensive development of the active tissue. Our results supported this findings and also showed pre-pubertal growth jump of the absolute fat mass (10-11th years, 1.29 kg), as well as it's decrease during and after puberty at expense of the growth of the absolute values of the muscle and residual mass. For intensive development of the muscle and bone mass, but lowest in fat mass of children announced and other investigators (Гурбо, 2005 and other).

The fig. 2 show that the relation between relative body mass components changed with age. Throughout the growth period the muscle tissue represents the highest percentage of boys total body mass, followed by bone tissue mass and the residual mass. The lowest of all is the fat tissue percentage. Muscle tissue percentage grows from 39.28 % at the beginning to 46.71% at the end of the period. The relative part of the muscle mass in total body weight significantly increases between the 7-8th, 11-12th and 16-17th years of age ($p<0.05$). Bone tissue increases its percentage until the age of 13 when it reaches almost 25 % of the total body weight and afterwards it decreases. The slightest changes are observed in fat tissue percentage- from 11.46% to 13.80%. The percentage of the fourth component-the residual, obviously decreases showing however certain fluctuations- from 27.57 % at the beginning to 17.92% at the end of the period.

Thirteen-year-old boys are characterized by the highest percentage of body fast (23.80%) and of osseous tissue (24.55%), but of the lowest percentage of residual mass (17,22 %), while the seventeen-year-olds have the highest percentage of muscle tissue (46.71%) mass.

Moreover the parameters assessed the fat, muscle and bone mass, special attention deserve also the values of skinfold thickness, muscle radii and bone diameters (fig.3), mainly because the body mass components dependent in different stage of the body height. The our results supported these of other similar research (Векслер, 1988) and show that the body height, bone diameters and muscle radii of boys increases parallel throughout the whole growth period. The thickness of subcutaneous fat tissue are change slightly and independently of the height.

The results of our research also show the puberty growth jump of body height and body weight of the investigated boys (fig.4). It's occurs between the years 13-14, when height increases by 10.9 cm and weight-by 6.94 kg. The intensity of body height growth abruptly decreases after 14, while the body weight continues to grow at a very high rate until the age of 15. In this period we observed change in growth tempo of four body components (fig.5). As can be seen from the figure absolute growth velocity of the muscle and residual mass increase parallelly, while the growth tempo of the bone and fat mass decrease. The changes in the development of muscle and fat components occur at the same age probabillity determine the future male structure of the body.

The analysis of relation between indices characterizing intensity of the growth i.e. the growth tempo of body components (fig.5) also show the highest absolute intensity of the muscle tissue, followed by bone and fat tissues.

During the all observed growth period (fig.6) the muscle component which grows 3.05 times is characterized by highest increase rate throughout the examined growth period. Slightly lower is the increase rate of the bone and fat component- 2.75 times, followed by body fluids mass (residuals mass) which rises only 1.66 times during the entire growth period.

As can be seen from obtain results the total body mass growth during the childhood have been different importance, structure and mechanism. It's base are the qualitative changes in body composition, which occur at certain stages of boys development and characterized with different relation between the fractions of body mass. Our findings supported these of previous research, which found a different relation between fat, muscle and bone tissue during the growth period (Векслер, 1988; Асенкевич, 2002; Arfai, 2002; Ogle et al. 1995; Molgaard, Fleischer-Michaelsen,1998; Nikolova, Mladenova, 2004; Гурбо, 2005 and other).

Except assessment of the absolute and relative values of body mass components, their relation and growth intensity we study also the relationship between tissue components, as well as between them and the total body meausurments-weight and height (Table 1, Table 2).

As can be seen in the Table 1, the development of the fat component is associated to a different extent with the development of muscle and bone components. The muscle tissue increase moderately depends on the changes in fat tissue mainly at the age of 8, 11 and 12. The increase of bone tissue mass is dependent on fat tissue growth only at the age of 13 and 17. During the remaining periods changes in the fat component depend, from a moderate to a significant extent, on the increase of bone mass. The results also show that the muscle development strongly depends on skeleton growth at the age of 8, 10-12 and 14 and less strongly during the other periods. Year 17 is an exception and changes of the mass of these components are independent on each other.

The body mass changes during the observed period depend much more on the changes of muscle and bone tissue than changes of fat tissue mass (Table 2). The height growth also is to a high degree associated with bone and muscle mass growth and does not depend on fat tissue changes. During the age of 13, 15 and 17 height increase is associated with the fat component decrease, while at 13-with that of the bone component. The slight link between the fat and osseous – muscle components shows their relative independence in the growth period.

CONCLUSION

Basing on the results of this research, the following conclusions can be made:

The growth of the total body mass during the childhood have been different importance, structure and mechanism. It's base are the qualitative changes in body composition, wich occur at certain stages of boys development and characterized with different relation between the fractions, constituting body mass.

The age interval of 13-14 is crucial for the development of the investigated boys. It is at this age that the puberty growth jump occurs when height increases by 11 cm on the average and weight-by 7 kg. The changes in the development of body mass components at this age and during the all observed growth period can be connect with the different specific growth effects on the body composition and with the determination the future male structure of the body.

Body mass changes of the boys with normal physical development and nutritional status are associated to a significantly higher degree with changes in muscle and bone tissues mass, than with fat tissue mass changes. This findings showed that for correct evaluation of children's physical development and nutritional status should be used not only signs, based on the weight – height relation, such as BMI, but also methods or technics allow to analyze the different fractions, constituting body mass.

REFERENCES

1.АСЕНКЕВИЧ, Р., 2002. Онтогенетическая изменчивост показателей физического развития и двигательных функций польских мальчиков и девочек 5-14 лет. Автореф. дисс. докт. биол.наук, Москва, 50 с.

2.ВЕКСЛЕР, А.,1988. Тканевые компоненты массы тела и их соотношения в динамике пубертатного развития мальчиков.,Вопр. Антропологии, Вып. 80, 62-70.

3.ГОДИНА, Е.З., 2001. Динамика процессов роста и развития у человека: пространственно-временные аспекты. Автореф. дисс.докт. биол.наук, Москва, 75 с.

4.ГУРБО, Т., 2005. Закономерности изменчивости физического развития детей беларуси в период первого детства. Автореф. дисс. канд. биол.наук, Минск, 20 с.

5.ЗАДОРОЖНАЯ, Л.В. 1998. Влияние социально-экономических факторов на морфо-функциональные характеристики детей и подростков. Автореф. дисс. канд.биол. наук, Москва, 23 с

6.ЧТЕЦОВ, В.,1970. Состав тела человека, Антропология 1969: Итоги науки, ВИНИТИ АН СССР, Москва, 128 с.

7.ARMSTRONG, J., 2003. The prevalence of obesity and undernutrition in Scotish Children: growth monitoring within the Child Health Sureillance Programme, Scotish Medical Journal, 48,2, 32-37.

8.ARFA, K., PITUKCHEEWANONT, P., GORAN, M., TAVARE, J., HELLER, L., GILSANZ, V., 2002. Bone, muscle and fat: sex-related differences in prepubertal children. Radiology, 224, 338-344.

9.BOLZANT, A., GUIMAREY, L., FRISANCHO, A., 1999. Study of growth in rural school children from Buenos Aires,Argentina using upper arm muscle area by height and other anthropometric dimensions of body composition. Ann. Hum Biol, 26, 185-193.

10.COLE, T., BELLIZZI, M., FLEGAL, K., DIETZ, W., 2000. Establishing a standard definition for child overweight and obesity worldwide:international survey. BMJ, 5, 320, 1-6.

11.COWELL, C.T, BIODY, J., LIOYD-JONES, S., SMITH, C., MOORE, B., HOWMAN-GILES, R. 1997. Fat distribution in children and adolescents: the influence of sex and hormones. Horm. Research, 48, 93-100.

12.DEURENBERG, P., PIETERS, J., HAUTVAST, J.G., 1990. The assessment of the body fat percentage by skinfold thickness measurments in childhood and young adolescence. Br.Jour. Nutr. 63, 293-303

13.FRISANCHO, A., 1984. New standarts of weight and body composition by frame size and height for assessment of nutritional status of adults and elderly. Am. Journ. of Clinical Nutrition, 40, 808-819.

14.HASCHKE, F.,1989.Body composition during adolescence. In;Klish W, Kretchmer N., eds. Body composition measurements in infants and children:report of the ninety-eight Ross conference on pediatric research. Columbus, Ohio: Ross Laboratories, 76-83.

15.HÄGER, A., SJÖSTRÖM, L., ARVIDSSON, B., BJÖRNTORP, P., SMITH, U.,1977. Body fat and adipose iossue cellularity in infants: a longitudinal study., Metabolosm; 26, 607-614
16.JAQUET, D., LEGER, J., TABONE, M.D., CZERNICHOW, P., LEVY-MARSHAL, C., 1999. High serum leptin concentrations during catch-up growth of children born with intrauterine growth retardation. J.Clin. Endocrinol. Metab. 82, 156-158.
17.MARTIN, R., SALLER, K. 1957. Lehrbuch der Anthropologie, Stuttgart: Custav Fisher Verlag, 1,661.
18.MCARDLE, W.D., KATCH, F.I., KATCH, V.L., 1986. Exercise Physiology., Philadelphia: Lea & Febiger.
19.MOLGAARD, C., MICHAELSEN, K.F., 1998. Changes in body composition during growth in healtly school-age children. Appl. Radiat.Isot, 49, 577-579.
20.NIKOLOVA, M., MLADENOVA, S., 2004. Anthropometric indicators for assessment of body composition. Acta morph., 10, p. 218-225, Sofia.
21.OGLE, G.D., ALLEN, J.R., HUMPHRIES, I.R.J. et al., 1995. Body-composition assessment by dual-energy x-ray absorptiometry in subjects aged 4-26 y., Am. Jour. Clin. Nutr., 61, 746-753.
22.PRADER, A., LARGO, R.H., MOLINARI, L., ISSLER, C., 1989; Physical growth of Swiss children from birth to 20 years of age: first Zurich longitudinal study of growth and development., Helv. Paediat. Acta Suppl., 52, 1-125.
23.RAMIREZ, M.E., 1993. Subcutaneous fat distibution in adolecents. Hum. Biol.; 65, 771-782.
24.RICO, H., REVILLA, M., VILLA, L.F., HERNANDEZ, E.R., ALVAREZ DE BUERGO, M., VILLA M. 1993. Body composition in children and Tanner's stages: a study with dual-energy x-ray absorptiometry. Metabolism, 42, 967-970.
25.ROLLAND-CACHERA, M.,1998. Body mass Index References. The Cambridge Encyclopedia of Human Crowth and Development., Eds. Ulijaszek S. Y., Yohnston F. E., Preece in M. A. Cambridge: Cambridge Univ. Press., 68-69.
26.ROLLAND-CACHERA, M.,1993. Body composition during adolescence: methods, limitations and determinants. Hormonal Research, 39, 25-40.
27.ROLLAND-CACHERA, M., BRAMBILLA, P., MANZONI, P., AKROUT, M., SIRONI, S., DEL MASCHIO A., CHUIMELLO, G., 1997. Body composition assessed on the basis of arm circumference and triceps skinfold thikness: a new index validated in children by magnetic resonance imaging. Am J Clin Nutr., 65, 6, 1709-1713.
28.World Health Organisation, 1995. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee, Geneva, 854.
29.World Health Organisation , 1997. Obesity: preventing and managing the global epidemic. Report of a WHO consultation on obesity, Geneva, 305.

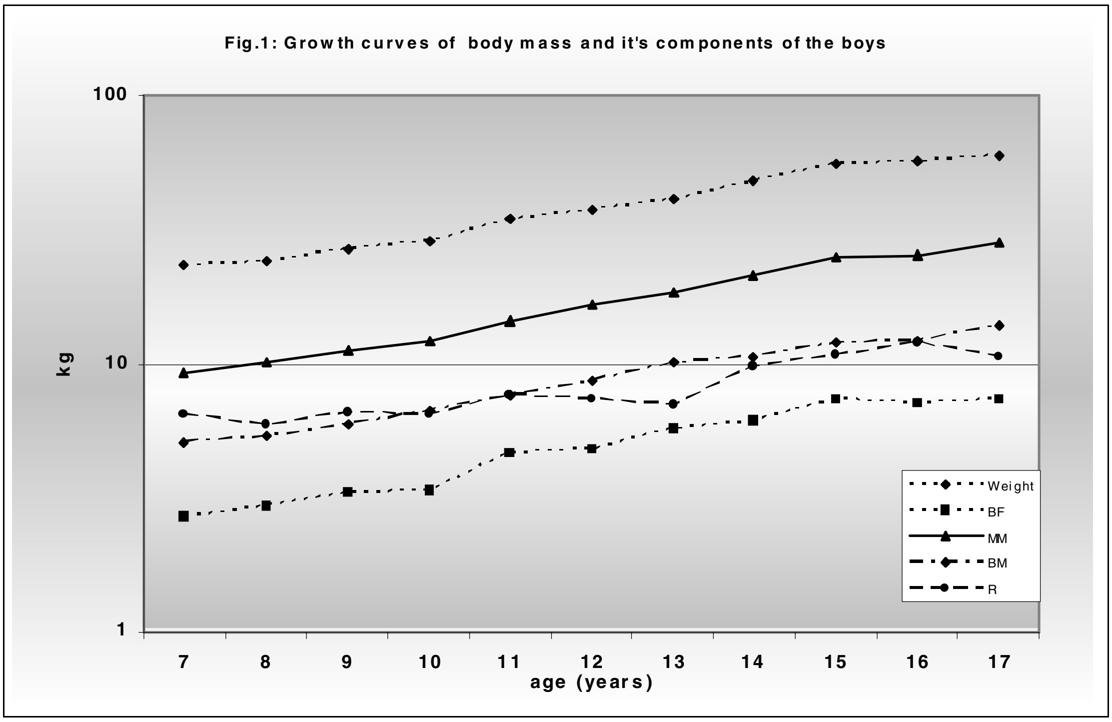


Fig.1: Growth curves of body mass and it's components of the boys
100
10
1
kg
7
8
9
10
11
12
13
14
15
16
17
age (years)
Weight
BF
MM
BM
R

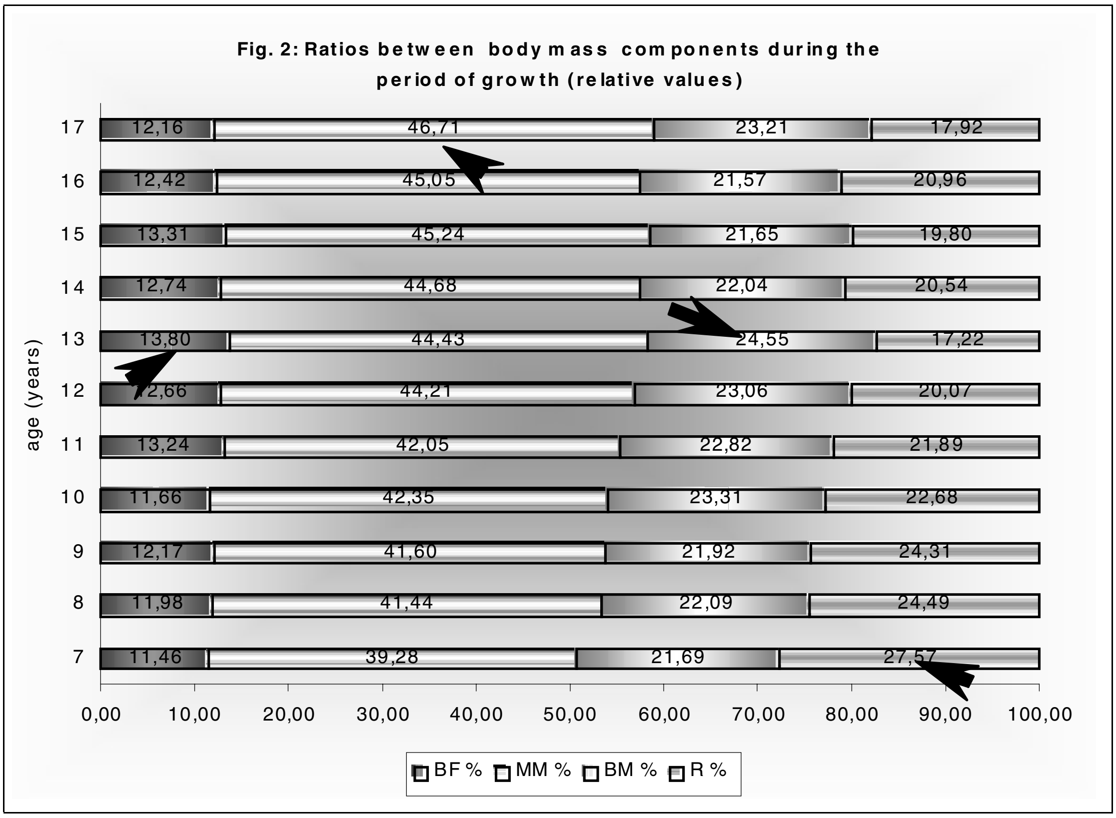


Fig. 2: Ratios between body mass components during the period of growth (relative values)
17
16
15
14
13
12
11
10
9
8
7
age (years)
12,16
46,71
23,21
17,92
12,42
45,05
21,57
20,96
13,31
45,24
21,65
19,80
12,74
44,68
22,04
20,54
13,80
44,43
24,55
17,22
12,66
44,21
23,06
20,07
13,24
42,05
22,82
21,89
11,66
42,35
23,31
22,68
12,17
41,60
21,92
24,31
11,98
41,44
22,09
24,49
11,46
39,28
21,69
27,57
0,00
10,00
20,00
30,00
40,00
50,00
60,00
70,00
80,00
90,00
100,00
BF %
MM %
BM %
R %

Fig. 3: Growth curves of the height, average epicondylar diameter and the muscle radius of limbs, and average thickness of subcutaneous fat tissue

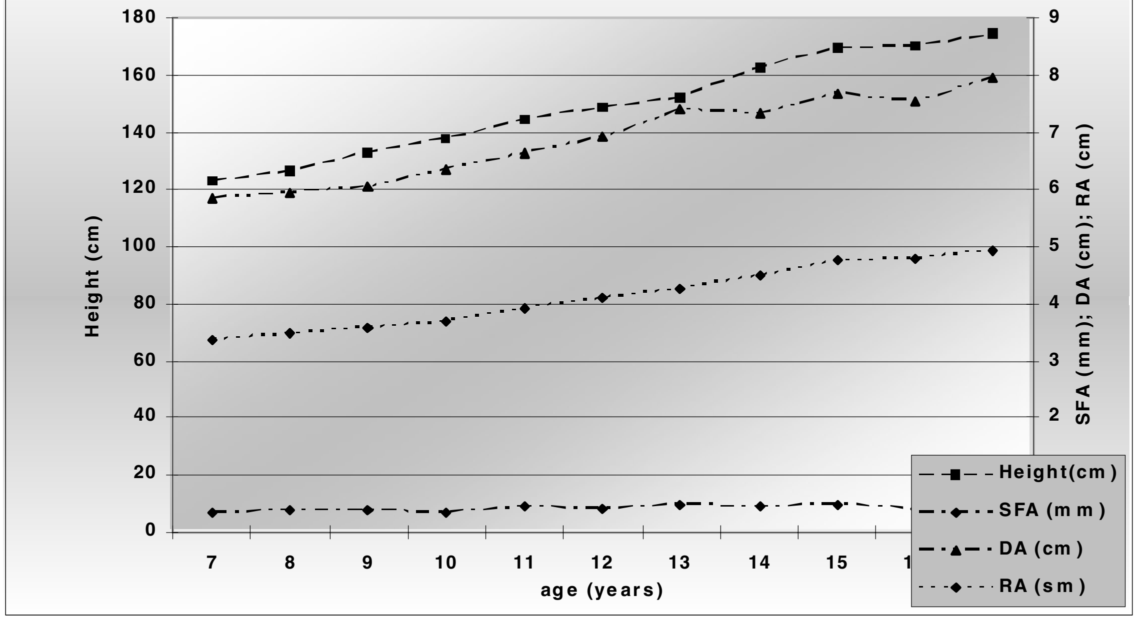
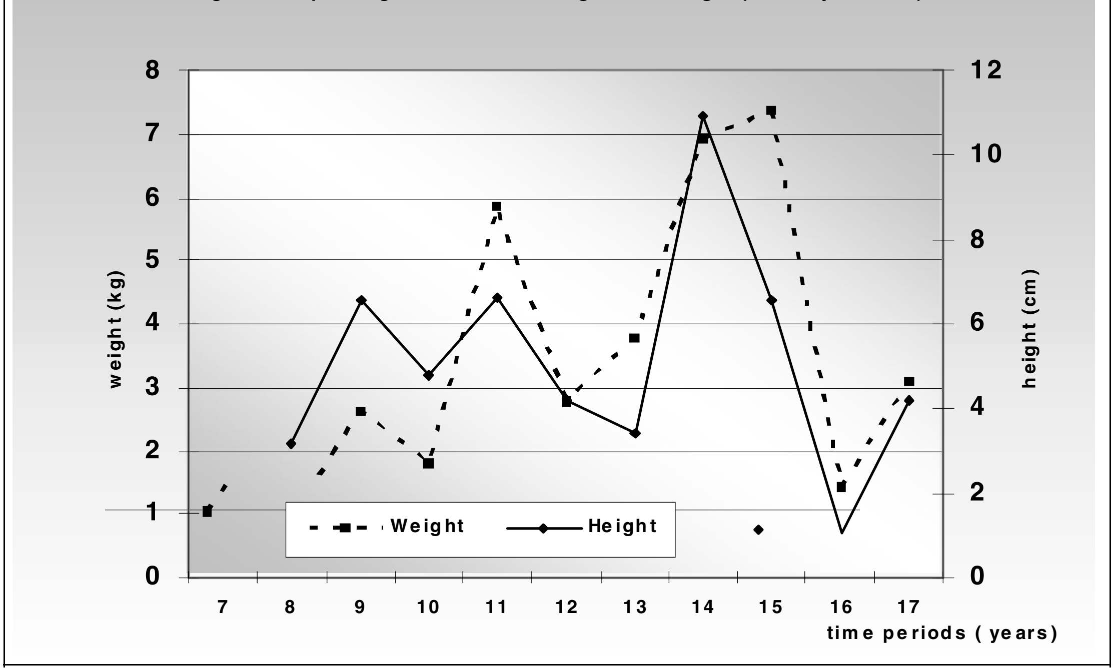


Fig.4 : Tempo of growth of the weight and height (velocity curves)



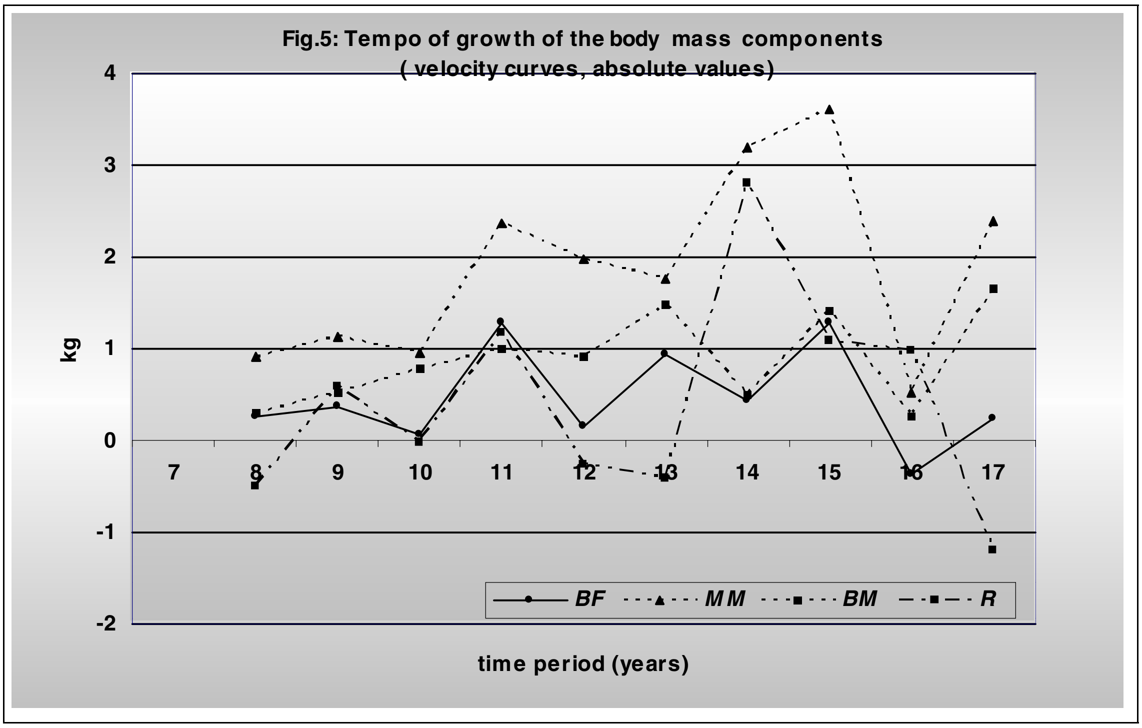


Fig.5: Tempo of growth of the body mass components
(velocity curves, absolute values)
kg
4
3
2
1
0
-1
-2
7
8
9
10
11
12
13
14
15
16
17
BF
MM
BM
R
time period (years)

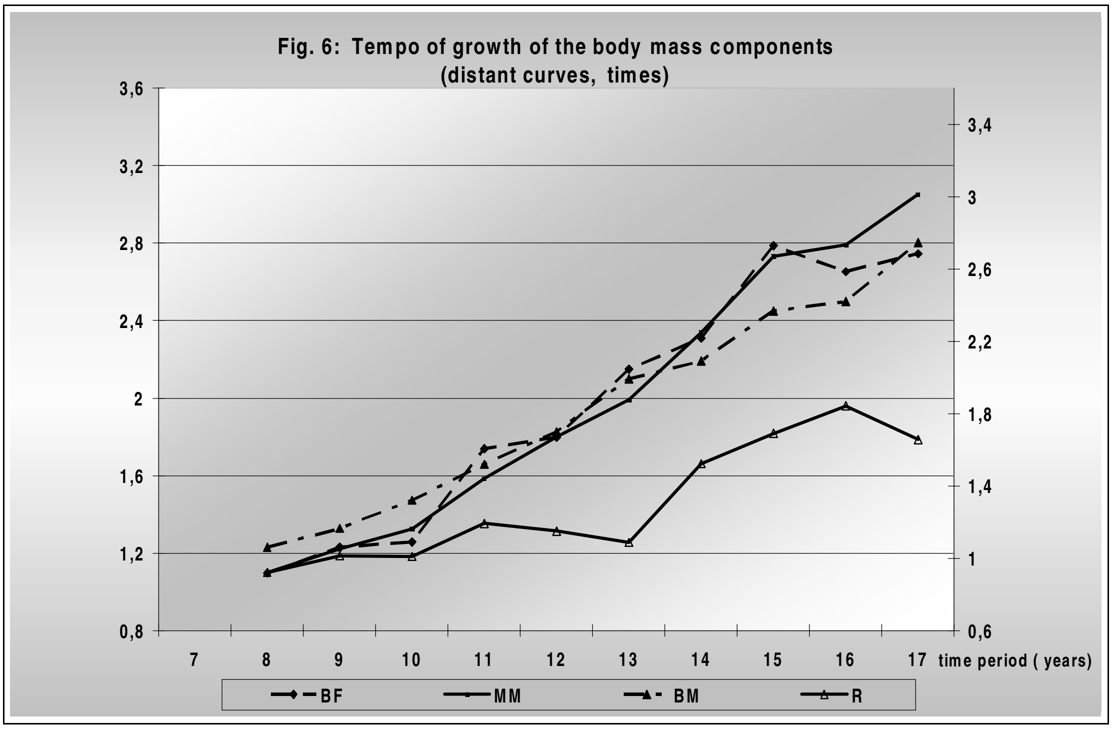


Fig. 6: Tempo of growth of the body mass components
(distant curves, times)
3,6
3,2
2,8
2,4
2
1,6
1,2
0,8
3,4
3
2,6
2,2
1,8
1,4
1
0,6
7
8
9
10
11
12
13
14
15
16
17
time period (years)
BF
MM
BM
R

Table 1. Correlations between the thickness of subcutaneous fat tissue, sum of muscle radii and bone diameters

Measurments	**Age (years)**	**Average skinfold (mm)**	**Sum of bone diameters (cm)**
Sum of muscle radii (cm)	7	-0.06	0.21
	8	0.62	0.78
	9	0.22	0.37
	10	0.48	0.85
	11	0.36	0.82
	12	0.48	0.85
	13	0.18	0.27
	14	0.20	0.76
	15	0.24	0.67
	16	0.06	0.61
	17	0.19	0.05
Sum of bone diameters (cm)	7	0.31	
	8	0.73	
	9	0.36	
	10	0.69	
	11	0.57	
	12	0.72	
	13	0.14	
	14	0.63	
	15	0.69	
	16	0.52	
	17	0.08	

Table 2. Correlations between height, weight, the thickness of subcutaneous fat tissue, sum of muscle radii and bone diameters

Measurments	Age (years)	Average skinfold (mm)	Sum of bone diameters (cm)	Sum of muscle radii (cm)
Weight (kg)	7	0.54	0.63	0.48
	8	0.66	0.87	0.86
	9	0.50	0.59	0.82
	10	0.67	0.87	0.88
	11	0.62	0.89	0.85
	12	0.62	0.87	0.88
	13	0.48	0.33	0.84
	14	0.45	0.85	0.83
	15	0.50	0.77	0.86
	16	0.34	0.85	0.79
	17	0.35	0.12	0.92
Height (cm)	7	0.30	0.52	0.18
	8	0.19	0.53	0.41
	9	0.10	0.38	0.51
	10	0.20	0.29	0.29
	11	0.20	0.67	0.66
	12	0.31	0.61	0.63
	13	-0.22	-0.15	0.42
	14	0.19	0.57	0.49
	15	-0.18	0.20	0.48
	16	-0.24	0.42	0.45
	17	-0.16	0.01	0.56