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Sex Differences in Morphological Dimensions in Twelve-Year-Old Children from Imotska Krajina

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A B S T R A C T

The aim of the study was to identify and compare morphological characteristics of 12-year-old male and female children from Imotska krajina. The structure of a set of 23 morphological space variables were determined in a sample of 75 male and 67 female children by use of factor analysis for each sex in separate. Factor structure showed two basic superior latent dimensions responsible for directly measurable manifestations of morphological parameters in both male and female children. One of these two dimensions behaved as a general mechanism of growth and development, whereas the other showed a bipolar pattern. Bipolarity was almost exclusively determined by adipose tissue on one pole, and by skeletal longitudinal growth on the opposite pole. Rotation of the main components to varimax position yielded two morphological dimensions that were well balanced in both sexes (slightly better in girls); besides the predominant increase in adipose tissue, one of these dimensions was also responsible for the development of muscular tissue and skeletal transverse development, whereas the other was responsible for skeletal transverse development and muscular tissue development in addition to the predominant longitudinal skeletal growth. These observations suggested two developmental processes, i.e. transverse morphological development (first factor) and longitudinal morphological development (second factor), to be almost equally involved in the morphological development of 12-year-old male and female children. These developmental processes are highly genetically determined and can only in part be explained by the intensity of kinesiologic engagement. Based on the morphological structures defined, discriminative function of the morphological space primarily differentiated two developmental processes, i.e. longitudinal skeletal development (hand length in particular) in female children relative to transverse skeletal development (knee diameter in particular) in male children, pointing to the presence of full-swing puberty in female children, while yet to be expected in male children; thereafter, the differences in the ectomesomorphic morphological characteristics would be by far more pronounced in favor of male children.

Key words: *morphological characteristics, male and female children, factor analysis*

Introduction

Morphological anthropometry is a method of human body measurement, processing and study of the measures obtained. Morphological anthropometry has found application in numerous fields, e.g., sports kinesiology, recreational and educational kinesiology, sports medicine, pediatrics, and school medicine to monitor growth in children and adolescents, as part of practical standard procedures for nutritional status assessment, in research into specific mor phological features during growth and development, correlation of body dimensions with other anthropological characteristics, and in anthropological studies of the population structure (Mišigoj-Duraković, 2008)[1].

Growth and development are the basic biologic feature of the child's body, whereby it develops into the maturing body under the influence of disposing factors, various environmental factors and its own activity (Malina, 1984; Forbes, 1987; Shepard, 1991; Malina and Bouchard, 1991)[2–6]. Body growth and development implies an increase in body mass and height, proportional changes, skeletal maturation, and anatomic-functional maturation of organs and organ systems.

Determination of specific morphological characteristics in various populations from some isolated localities is of great scientific importance for providing a basis for the study of genetic determination of morphological characteristics in particular eco-social settings. In addition, it enables identification of the genetic and non-genetic mechanisms responsible for determination of the size, shape and structure of the human body.

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Studies of the structure of morphological characteristics have mostly been performed in stable samples, i.e. samples of subjects with minor result oscillations. This produced relatively reliable indicators of the final morphological structure and relations among dimensions that can be considered definitive and permanent.

A number of factor studies have confirmed the number and structure of latent dimensions to sustain no major changes under the influence of the choice of manifest variables or due to minor differences in sample selection, provided the variables and samples are representative, and the conditions of data collection and methods of processing are correct (Stojanović et al., 1987; Hošek, 1987; Hofman and Hošek, 1985; Bala, 1977; Szirovicza et al., 1980)[7–11].

However, all these results were obtained in samples that almost regularly represented a population with their growth and development having reached final stages. These results indicate that four morphological dimensions can generally be identified in adults. In adolescents, a three-dimensional model has been described (Kurelić et al., 1975)[12], whereas two morphological dimensions exist in children of both sexes aged 6–10 (Katić et al., 1994, Katić et al., 1996; Katić 2003)[13–15].

According to current state-of-the-art, intensive growth and development occurs up to 5 years of age, followed by slowing down for some 3–4 years, then intensifying again to the age of 16–17. On the other hand, the elements of endocrine system undergo constant intensive development to the adolescence, when it shows marked decline. And finally, genital development intensifies after the age 13–14.

These general developmental tendencies reflect upon all other body sub-systems that are tightly inter-related and therefore should be observed in a multi-segmental and multidisciplinary manner whenever possible (Ismail, 1972; Ismail, 1976; Moskatova, 1986; Katić et al., 1994; Katić, 2003)[16–18,13,15]. So, in a study from 2003, Katić applied a programmed 18-month kinesiologic treatment in a sample of 487 (249 male and 236 female) children aged 7 years. Taxonomic analysis of the morphological-motor space isolated three taxonomic variables at three measurement points for each sex. In female subjects, development occurs at a faster rate and the following three morphological-motor structures listed in the order of dominance are formed earlier: ectomesomorphic, motor and endomorphic structures. In children of both sexes, the morphological taxons describe two opposite sides of development, ectomesomorphy as a positive facet of development and increased endomorphy as a negative facet of development. Ectomesomorphy shows positive correlation and endomorphy negative correlation with motor abilities.

However, the Heath-Carter method of somatotype determination, widely used worldwide (Heath, 1977; Carter and Heath, 1990; Carter and Heath, 1992)[19–21], is considerably less precise than taxonomic analysis (a considerable body of information is lost), but is more attractive, probably due to its simple use. For instance, it was employed by Parizikova and Carter (1977)[22] in boys; Carter (1984)[23] in track-and-field athletes; Bale et al. (1992)[24] in young track-and-field athletes; Gualdi-Russo and Graziani (1993)[25] in athletes; Štepnička (1977)[26], etc.

In a sample of 2235 female children (divided into four subgroups), elementary school first- to fourth-graders from Primorje-Gorski kotar County, Katić et al. (2004)[27] demonstrated the morphological-motor functioning to change in dependence of age. Developmental processes lead to the formation of a general morphological factor defined as ectomesomorphy and two general mechanisms responsible for motor efficiency in the form of force regulation and speed regulation. In this study, the authors also showed the morphological set of only four variables to be adequate to obtain basic information on the characteristics of morphological development in female children aged 7–11. Briefly, developmental processes tend to establish optimal relationships among all somatotype constituent elements. Then, these relationships determine motor efficiency due to interactions between the morphological and motor systems.

Morphological structure as a sub-segment of the anthropological system enables due performance of motor manifestations. Acting upon development of motor abilities implies acting upon development of the body as a whole, i.e. its structure and composition. This entails changes in the morphological structure, and these changes in turn lead to higher motor efficiency and further development of motor abilities.

Aim of the study

The aim of the study was to determine morphological characteristics of 12-year-old male and female children from Imotska krajina. Descriptive parameters of variable distributions were analyzed first, followed by factor structure of space defined by anthropometric variables, for each sex in separate. Finally, structural and quantitative differences according to sex were analyzed for complete description of the morphological characteristics of male and female children.

Subjects and Methods

Subject sample

Study sample included 142 elementary school sixth-graders (75 male and 67 female) aged 12 years ± 2 months.

Variable sample

A set of 23 variables were used on morphological dimension assessment:

- longitudinal skeleton dimensionality: body height (mm), arm length (mm), leg length (mm), foot length (mm), hand length (mm);
- transverse skeleton dimensionality: shoulder width (mm), pelvis width (mm), wrist diameter (mm), elbow diameter (mm), knee diameter (mm), hand width (mm), foot width (mm);

- body mass and volume: body weight (dkg), upper arm circumference (mm), forearm circumference (mm), upper leg circumference (mm), lower leg circumference (mm), mean chest circumference (mm); and
- subcutaneous adipose tissue: axilla skinfold (1/10 mm), subscapular skinfold (1/10 mm), abdomen skinfold (1/10 mm), triceps skinfold (1/10 mm), lower leg skinfold (1/10 mm).

Measurements were taken in November 2008 in line with the International Biological Program (IBP) instructions[28,29]. Measurements were performed by five physical education teachers additionally educated and properly trained, in the morning, taking two periods *per* subject *per* week.

Data processing

Data obtained were processed by standard descriptive procedures to determine the functions of their distribution and the basic statistical parameters of these functions. Calculations included arithmetic mean (Mean), standard deviation (SD), minimal result (Min), maximal result (Max), asymmetry coefficient (Skew), and kurtosis coefficient (Kurt). The hypothesis of distribution normality was tested by Kolmogorov-Smirnov procedure according to which the hypothesis can be rejected with an error of 0.01.

Hotelling method of main components was employed to determine latent structure of the morphological space. In the present study, Guttman-Kaiser criterion was used, according to which the components with characteristic roots greater or equal to 1.00 are considered significant. The characteristic roots of the inter-correlation matrix were marked with λ (Lambda). In addition to the size of characteristic roots, the relative cumulative contribution of each root to the explanation of the overall variable variance was also calculated.

Significant main components were transformed to varimax position to determine a simpler structure.

Canonic discriminative analysis[30] was used to identify differences in morphological variables between male and female children. Discriminative function (DF), F-test for ANOVA, significance for ANOVA (p^A) and coefficient of canonic discrimination (Delta) with significance ($p<0.001$) were calculated.

Results and Discussion

Descriptive parameters of the anthropometric measures recorded in our study subjects are presented in Table 1 (male children) and Table 2 (female children). The following values were calculated: arithmetic mean (Mean),

TABLE 1
DESCRIPTIVE STATISTICS OF ANTHROPOMETRIC VARIABLES IN MALE CHILDREN (N=75)

Variable	Mean	SD	Min	Max	Skew	Kurt
Body height	158.80	8.09	144.40	174.10	0.14	–0.78
Leg length	94.23	5.18	84.30	104.10	0.16	–1.03
Arm length	68.71	3.84	61.43	76.20	–0.05	–0.76
Hand length	15.99	0.95	14.37	17.80	0.18	–1.08
Foot length	24.58	1.27	22.17	26.60	–0.16	–0.93
Shoulder width	32.53	2.02	28.33	37.43	–0.02	–0.45
Pelvis width	24.15	1.80	20.43	28.20	0.15	–0.68
Hand width	7.23	0.48	6.23	8.20	–0.20	–0.69
Foot width	8.36	0.66	7.10	9.70	0.08	–0.72
Wrist diameter	5.05	0.42	4.20	5.83	–0.08	–0.85
Elbow diameter	6.38	0.51	5.33	7.40	–0.25	–0.73
Knee diameter	9.87	0.82	8.03	11.70	0.05	–0.48
Body weight	48.96	10.65	31.50	72.20	0.27	–0.99
Upper arm circumference	24.36	3.80	18.17	34.23	0.60	–0.09
Forearm circumference	22.10	2.32	17.27	28.10	0.14	0.02
Upper leg circumference	47.33	6.13	36.10	62.17	0.46	–0.31
Lower leg circumference	32.52	3.57	25.90	42.43	0.46	0.02
Mean chest circumference	75.22	8.12	63.17	98.33	0.78	0.21
Triceps skinfold	13.85	6.72	1.73	26.53	0.31	–0.75
Subscapular skinfold	9.30	5.78	2.07	25.82	1.21	0.90
Axilla skinfold	9.64	6.64	2.07	26.60	1.08	0.17
Abdomen skinfold	15.24	11.34	2.07	42.80	0.89	–0.50
Lower leg skinfold	15.68	7.98	2.07	35.60	0.61	–0.34

Mean – arithmetic mean, SD – standard deviation, Min – minimal result, Max – maximal result, Skew – coefficient of asymmetry, Kurt – coefficient of kurtosis standard deviation (SD), minimal value (Min), maximal value (Max), skewness as a measure of asymmetry assessment (Skew), and kurtosis as a measure of elongation or flatness assessment (Kurt). Generally, this set of 23 anthropometric variables for morphological status assessment showed no major deviation from the values characteristic of normal distribution in either sex group (skewness = 0; kurtosis = 0). Careful inspection of Tables 1 and 2 reveals both parameters (skewness and kurtosis) to range from –1 to 1, with the exception of some measures assessing voluminosity (subscapular skinfold and axilla skinfold), where the values of parameters of asymmetry assessment exceed 1, indicating a greater proportion of study subjects with extremely high values. This holds for both sexes. In contrast to asymmetry, kurtosis pointed to substantial sex differences in subscapular skinfold and axilla skinfold. In male children these values were within the limits of normal data distribution, whereas in female children moderate platikurtosis was observed for subscapular skinfold (1.46) and axilla skinfold (1.33), pointing to a significantly weaker result clustering around arithmetic mean. Such a pattern of distribution in these two measures could be ascribed to the initial stage of intensive morphological developmental processes that start much earlier in female than in male children. Considering other anthropological variables, only some measures assessing longitudinal bone growth yielded increased negative values of the kurtosis parameter, i.e. stronger clustering of results around arithmetic mean. In male children, this applied to leg length (–1.03) and hand length (–1.08), and in female children to arm length (–1.21) and hand length (–1.18).

Many anthropological studies evaluated morphological variables by use of various methodologies. In spite of different techniques of extraction and very variable criteria for the basic space transformation employed, in most studies similar results were generally obtained on defining their latent structure.

Based on the Guttman-Kaiser criterion, according to which the components with characteristic roots greater or equal to 1.00 are considered significant, two significant characteristic roots were isolated and proved adequate to explain 83% of total variance in the system of morphological variables (Table 3).

The main components of the matrix of variable inter-correlations were calculated on the basis of the characteristic roots extracted and their respective characteristic vectors (Table 3).

The first main component was responsible for 66% of variance of the entire system of variables and assumed the role of general growth and development factor. All

TABLE 2
DESCRIPTIVE STATISTICS OF ANTHROPOMETRIC VARIABLES IN FEMALE CHILDREN (N=67)

Variable	Mean	SD	Min	Max	Skew	Kurt
Body height	159.42	7.26	144.80	174.23	0.22	–0.72
Leg length	94.51	4.58	84.23	104.27	0.19	–0.73
Arm length	68.92	3.94	63.27	76.47	0.21	–1.21
Hand length	16.19	0.97	14.13	17.80	–0.03	–1.18
Foot length	24.04	1.08	22.07	26.40	0.11	–0.80
Shoulder width	32.47	2.08	28.07	37.17	–0.02	–0.75
Pelvis width	23.83	1.85	20.00	27.43	–0.09	–0.40
Hand width	7.07	0.47	6.13	8.00	–0.01	–0.76
Foot width	8.17	0.59	6.93	9.63	0.13	–0.44
Wrist diameter	4.91	0.32	4.17	5.53	–0.20	–0.53
Elbow diameter	6.07	0.43	5.23	7.12	0.31	–0.36
Knee diameter	9.41	0.86	8.10	11.87	0.77	0.55
Body weight	47.71	9.91	31.60	72.10	0.41	–0.13
Upper arm circumference	23.39	3.55	17.33	32.30	0.59	–0.01
Forearm circumference	21.06	1.99	17.33	26.33	0.38	–0.01
Upper leg circumference	47.66	6.03	36.33	64.27	0.55	0.48
Lower leg circumference	32.12	3.48	26.00	41.33	0.31	–0.30
Mean chest circumference	75.64	7.64	63.33	98.67	0.65	0.44
Triceps skinfold	14.79	5.68	4.13	25.20	–0.04	–0.82
Subscapular skinfold	10.39	5.34	2.53	26.10	1.10	1.46
Axilla skinfold	10.33	5.52	2.07	26.20	1.10	1.33
Abdomen skinfold	14.82	8.33	2.67	38.10	0.81	0.30
Lower leg skinfold	16.52	7.10	2.07	33.27	0.43	0.11

Mean – arithmetic mean, SD – standard deviation, Min – minimal result, Max – maximal result, Skew – coefficient of asymmetry, Kurt – coefficient of kurtosis

TABLE 3
FACTOR ANALYSIS OF ANTHROPOMETRIC VARIABLES IN MALE CHILDREN (N=75)

Variable	H1	H2	h^2	V1	V2
Body height	–0.75	–0.57	0.92	0.14	0.93
Leg length	–0.70	–0.55	0.84	0.12	0.88
Arm length	–0.76	–0.48	0.86	0.21	0.88
Hand length	–0.69	–0.56	0.78	0.10	0.88
Foot length	–0.73	–0.54	0.87	0.15	0.90
Shoulder width	–0.79	–0.33	0.81	0.34	0.78
Pelvis width	–0.89	–0.02	0.85	0.63	0.64
Hand width	–0.69	–0.44	0.76	0.19	0.79
Foot width	–0.80	–0.28	0.79	0.38	0.75
Wrist diameter	–0.81	–0.32	0.78	0.36	0.79
Elbow diameter	–0.85	–0.11	0.82	0.54	0.67
Knee diameter	–0.89	0.01	0.84	0.64	0.61
Body weight	–0.96	0.04	0.95	0.72	0.64
Upper arm circumference	–0.90	0.32	0.92	0.87	0.39
Forearm circumference	–0.91	0.12	0.92	0.74	0.55
Upper leg circumference	–0.90	0.26	0.91	0.83	0.44
Lower leg circumference	–0.93	0.11	0.93	0.75	0.57
Mean chest circumference	–0.92	0.25	0.94	0.83	0.46
Triceps skinfold	–0.67	0.61	0.85	0.90	0.03
Subscapular skinfold	–0.76	0.56	0.92	0.94	0.12
Axilla skinfold	–0.75	0.60	0.94	0.96	0.09
Abdomen skinfold	–0.78	0.56	0.95	0.95	0.14
Lower leg skinfold	–0.78	0.48	0.87	0.89	0.20
λ	15.22		3.81		
Variance %	66.16		16.55		

H – main component of inter–correlation matrix, h^2 – communality of measuring instruments, V – varimax factor, λ – characteristic root (Lambda), Variance % – percentage of explained variance

TABLE 4
FACTOR ANALYSIS OF ANTHROPOMETRIC VARIABLES IN FEMALE CHILDREN (N=67)

Variable	H1	H2	h^2	V1	V2
Body height	–0.72	–0.52	0.93	0.15	0.87
Leg length	–0.72	–0.49	0.89	0.18	0.85
Arm length	–0.77	–0.41	0.87	0.27	0.83
Hand length	–0.54	–0.63	0.76	0.05	0.83
Foot length	–0.60	–0.49	0.71	0.10	0.77
Shoulder width	–0.79	–0.40	0.80	0.29	0.83
Pelvis width	–0.84	–0.16	0.80	0.50	0.70
Hand width	–0.78	–0.21	0.84	0.41	0.69
Foot width	–0.83	–0.21	0.79	0.45	0.73
Wrist diameter	–0.69	–0.38	0.78	0.24	0.75
Elbow diameter	–0.78	–0.12	0.74	0.47	0.63
Knee diameter	–0.90	0.11	0.84	0.72	0.54
Body weight	–0.97	0.05	0.98	0.74	0.64
Upper arm circumference	–0.88	0.21	0.92	0.79	0.46
Forearm circumference	–0.93	0.09	0.93	0.74	0.57
Upper leg circumference	–0.90	0.18	0.90	0.77	0.50
Lower leg circumference	–0.91	0.18	0.92	0.78	0.50
Mean chest circumference	–0.93	0.06	0.94	0.71	0.60
Triceps skinfold	–0.67	0.61	0.87	0.91	0.02
Subscapular skinfold	–0.78	0.51	0.93	0.91	0.17
Axilla skinfold	–0.74	0.57	0.95	0.93	0.10
Abdomen skinfold	–0.73	0.52	0.85	0.88	0.13
Lower leg skinfold	–0.76	0.54	0.93	0.92	0.14
λ	14.59		3.42		
Variance %	63.44		14.86		

H – main component of inter-correlation matrix, h^2 – communality of measuring instruments, V – varimax factor, λ – characteristic root (Lambda), Variance % – percentage of explained variance

variables yielded high correlations with this factor, which is beyond doubt the first and foremost item to be measured of all elements of the morphological system of variables. The variables of body weight, lower leg circumference and chest circumference showed highest projections upon this factor.

The second main component accounted for 16% of the entire system variance with a taxonomic character, where longitudinality measures are found on one pole and skinfolds on the other pole. This main component obviously differentiates shorter individuals with more adipose tissue from those of taller stature and less subcutaneous fat and volume. Accordingly, the second main component distinguishes ectomorphic from endomorphic constitutional types.

On communality vector, the greatest amount of valid variance was explained in the variables of abdomen skinfold, followed by body weight and axilla skinfold.

The picture was by far more transparent when main components were transformed to varimax position. Varimax solutions provide a very suitable system for variable taxonomization; as factors can be also be viewed as taxons, there is no doubt that varimax transformation enables straight insight into the structure of latent dimensions.

The first latent dimension is strongly influenced by subcutaneous adipose tissue, and body mass and volume, thus representing an integrated dimension. In this stage of development, deposition of subcutaneous adipose tissue and muscle mass increase appear to occur in parallel.

The second factor is latent dimension primarily responsible for skeletal longitudinal development and considerably less for skeletal transverse development. Body height is predominantly influenced by skeleton longitudinality, followed by hand length, leg length and arm length. The measures of transverse skeleton dimensionality, i.e. wrist diameter, pelvis width and hand width, have high projections upon this dimension.

It is concluded that the structure of dimensions isolated in the present study is not simple enough to justify

TABLE 5
RESULTS OF DISCRIMINATIVE ANALYSIS OF ANTHROPOMETRIC VARIABLES BETWEEN BOYS AND GIRLS

Variable	Boys Mean	Girls Mean	DF	F^A	p^A
Body height	158.80	159.42	0.277	0.48	0.49
Leg length	94.23	94.51	0.075	0.06	0.81
Arm length	68.71	68.92	0.146	0.23	0.63
Hand length	15.99	16.19	0.760	11.86	0.00
Foot length	24.58	24.04	–0.072	1.48	0.23
Shoulder width	32.53	32.47	–0.108	0.17	0.68
Pelvis width	24.15	23.83	–0.010	0.00	0.97
Hand width	7.23	7.07	0.284	1.51	0.22
Foot width	8.36	8.17	–0.072	0.08	0.78
Wrist diameter	5.05	4.91	–0.414	3.15	0.08
Elbow diameter	6.38	6.07	–0.550	5.01	0.03
Knee diameter	9.87	9.41	–1.066	14.95	0.00
Body weight	48.96	47.71	–0.663	1.30	0.26
Upper arm circumference	24.36	23.39	–0.366	0.85	0.36
Forearm circumference	22.10	21.06	–0.782	3.81	0.05
Upper leg circumference	47.33	47.66	1.081	8.77	0.00
Lower leg circumference	32.52	32.12	0.673	2.70	0.10
Mean chest circumference	75.22	75.64	0.830	3.85	0.05
Triceps skinfold	13.85	14.79	0.460	2.33	0.13
lparSubscapular skinfold	9.30	10.39	0.531	1.67	0.20
Axilla skinfold	9.64	10.33	0.114	0.06	0.81
Abdomen skinfold	15.24	14.82	–0.784	4.45	0.04
Lower leg skinfold	15.68	16.52	0.094	0.07	0.79
Delta		0.54*			

DF – discriminative function, F^A – F-test for ANOVA, p^A – significance for ANOVA, Delta – coefficient of canonic discrimination, *p<0.001

the classic hypothesis on morphological dimension differentiation into pure components.

Factor analysis of the morphological space structure in female children (Table 4) revealed only two extensive mechanisms to be responsible for complete definition of the overall space. The main components serve as reproduction of the situation described by correlation matrix, according to which there is a single predominant mechanism in the formation of the morphological developmental basis, and another mechanism present to a lesser extent and differentiating longitudinal skeletal growth from adipose tissue increase.

The structure of the first main component is responsible for 63% of total variance of anthropometric measures. The measures of body mass and volume and of subcutaneous adipose tissue had high projections upon the first main component, whereas lower projections were observed for the measures of transverse and longitudinal skeleton dimensions. The first main component behaved as the general factor of growth and development, which is compatible with the results reported from other studies. General factor of growth and development was predominantly determined by the measures of volume, followed by the measures of subcutaneous adipose tissue. The logical quality of this phenomenon manifests in the set of anthropometric measures of circumference and subcutaneous adipose tissue selected, where the measures of subcutaneous adipose tissue are sub-summed on determining the body volume measures.

A bipolar character characterizes the second component isolated in the study, which explains 14.8% of total anthropometric measure variance with high projections of the measures of longitudinal skeleton dimensions and lower projections of transverse skeleton dimensions on negative pole, whereas the skinfold and volume measures are found on the opposite, positive pole. Based on previous studies, many authors refer to this phenomenon as to skeletomorphy-pyknomorphy, describing it as a consequence of the general growth and development factor partialization.

The communality of morphological measures was high, ranging from 0.73 to 0.98. The highest values were yielded by the measures of voluminosity, and lowest by transverse measures of skeleton dimensionality.

Varimax rotation isolated two factors. The first factor was defined by highest projections of the measures of subcutaneous fat and considerably lower projections of the body mass and volume. Also, a high projection of the measure of knee diameter should be noted. In this stage of growth and development, deposition of subcutaneous adipose tissue and muscle mass increase obviously occur in parallel, accompanied by development of transverse skeleton dimension. Accordingly, the first varimax factor has the characteristics of the endomesomorphic somatotype, to a lesser extent accompanied by transverse skeleton development.

The second varimax factor was predominantly defined by the measures of skeleton longitudinal dimension, which was to a great extent accompanied by the measures of transverse skeleton dimension development and measures of body mass and volume development. This second varimax factor displayed the characteristics of ectomesomorphic somatotype.

In female 12-year-old children, the function of the first factor-mechanism responsible for the formation of the endomesomorphic somatotype was found to predominate, accompanied by transverse skeleton development. Such morphological features were recognizable in the majority of sample subjects. However, in a small yet significant number of subjects, the function of the second mechanism responsible for the formation of the ectomesomorphic and/or athletic somatotype was recorded. The predominance of endomorphy (first factor) was related to the fact that female children of this age show systemic movement insufficiency and inability to meet many biopsychosocial needs.

In previous age, developmental functions of the skeleton had obviously been primarily focused on longitudinal growth of the skeleton and only then on the growth and development of other tissues. The pronounced longitudinal growth was primarily intensified, followed by the continuous development of other segments. Female children of this age are characterized by pronounced hormonal activity directed towards sexual maturity and reproduction later in life, which requires the total body mass and volume to be accomplished as early as possible. This can be most efficiently achieved through elongation of two axes, longitudinal first, and then transverse. In this way, an adequate mass as well as preconditions for the development of all internal thoracic and abdominal organs are ensured.

Canonic discriminative analysis (Table 5) revealed significant sex differences in the manifest morphological space. Discriminative function is bipolar and differentiates female children with pronounced longitudinal skeleton measures (only hand length being significant) and greater measures of upper leg circumference and chest circumference that are considerably saturated by adipose tissue, from male children with more pronounced transverse skeleton measures (knee diameter in particular) and measures of forearm circumference and lower leg circumference that are to a great extent saturated by muscle tissue.

Conclusion

Factor analysis was used to determine the structure of a set of 23 variables of the morphological space in a sample of male and female children from Imotska krajina. On factor analysis, the main components of the correlation matrix were analyzed first, followed by varimax factors obtained by the respective rotation of the main components. In both sexes, the first main component showed a pattern of the general mechanism of growth and development, whereas the second one yielded a bipolar pattern, being predominantly determined by adipose tissue on one pole and by longitudinal skeletal growth on the other pole. Varimax factors differentiated two processes of morphological development in both male and female children aged 12; one of these processes was predominantly characterized by the development of soft tissues, and the other, less pronounced, by skeleton development. These processes exerted a wide range of regulation with a number of process features; so, one process regulated development of adipose tissue and muscular tissue as well as transverse skeleton development in parallel, while the other regulated longitudinal and transverse skeleton development and muscle tissue development in parallel. The defined processes differed signifi- cantly according to the pronounced adipose tissue in the first and marked longitudinal skeleton growth in the second, which in turn resulted in the formation of the endomesomorphic somatotype accompanied by transverse skeleton development *versus* formation of the ectomesomorphic somatotype.

The observed compatibility of morphological structures in male and female children aged 12 could on the one hand be explained by faster development and/or sexual maturation in female than in male children, and on the other hand by equal exposure to physical activities and/or load in male and female children, considering specific conditions and lifestyle in Imotska krajina where children perform all physical activities irrespective of sex.

The fact that these 12-year-old male and female children have reached variable developmental stages is supported by the results of discriminative analysis. Although sex difference in morphological characteristics was significant, it was considerably lower than expected after puberty, i.e. in the final, definitive stage of development. This means that at this age female children catch up with or even leave behind male children, e.g., in body height. In line with this, discriminative function of the morphological space differentiated primarily two developmental processes, longitudinal skeleton development (hand length in particular) in female children *versus* transverse skeleton development (knee diameter in particular) in male children. Wider bones ensure better hold for the muscles, thus in part enabling development of greater muscle mass in male children relative to female children. Then the total body mass and volume will be to a greater extent saturated by muscle tissue in male children and by adipose tissue in female children. The children of both sexes from Imotska krajina are characterized by marked development of all somatotype components, i.e. endomorphy, mesomorphy and ectomorphy.

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SPOLNE DIFERENCIJACIJE MORFOLOŠKIH DIMENZIJA DVANAEST GODIŠNJE DJECE IMOTSKE KRAJINE

SAŽETAK

Istraživanje je imalo za cilj utvrditi i komparirati morfološke karakteristike dvanaest godišnjih dječaka i djevojčica Imotske krajine. U tu svrhu na uzorku od 75 dječaka i 67 djevojčica primjenom faktorske analize utvrđena je struktura skupa od 23 varijable morfološkog prostora i to posebno za svaki spol. Faktorska struktura kod dječaka i kod djevojčica je pokazala kako su prisutne dvije osnovne nadređene latentne dimenzije odgovorne za direktno mjerljive manifestacije morfologijskih parametara. Prva se ponaša kao generalni mehanizam rasta i razvoja, a druga je bipolarna. Bipolarnost je na jednom polu određena gotovo isključivo masnim tkivom a na suprotnom rastom skeleta u dužinu. Rotacijom glavnih komponenti u varimax poziciju dobivene su dvije morfološke dimenzije koje su dobro izbalansirane kod oba spola (neznatno bolje kod djevojčica), na način da je prva odgovorna uz dominantni porast masnog tkiva i za razvoj mišićnog tkiva i rasta skeleta u širinu, dok je druga odgovorna uz dominantni rast skeleta u visinu (dužinu) i za rast skeleta u širinu i razvoj mišićnog tkiva. Ovo navodi na zaključak kako su u morfološkom razvoju dvanaestogodišnjih dječaka i djevojčica gotovo na istovjetan način prisutna dva razvojna procesa: morfološki razvoj u širinu (prvi faktor) i morfološki razvoj u dužinu (drugi faktor). Ovi su razvojni procesi znatno genetski determinirani, te se samo dijelom mogu objasniti intenzitetom kineziološke angažiranosti. U skladu utvrđenih morfoloških struktura, diskriminativna funkcija morfološkog prostora diferencira primarno dva razvojna procesa: razvoj skeleta u dužinu (posebno dužinu šake) kod djevojčica u odnosu na razvoj skeleta u širinu (posebno dijametar koljena) kod dječaka, što ukazuje da je pubertetski zamah kod djevojčica već prisutan, dok će kod dječaka tek uslijediti i nakon kojeg će razlike u ekto-mezomorfnim morfološkim obilježjima biti znatno više izražene u korist dječaka.