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Trend of Relations between Morphological Characteristics and Motor Abilities in Preschool Children

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A B S T R A C T

Measurements of eight anthropometric characteristics and a battery of seven motor tests were applied in a large sample of 1170 children, 565 boys and 605 girls aged 4 to 7.5 decimal years from preschool institutions in three towns in Vojvodina (Novi Sad, Sombor, and Bačka Palanka). Children were selected according to 0.5 decimal years in the mentioned age range. The status of boys and girls according to seven age categories, age-related differences between boys and girls, as well as the relations between anthropometric characteristics and motor abilities were analyzed by use of intercorrelation matrices and canonical correlation analysis. Generally, significant sex differences were found in anthropometric characteristics, i.e. the values of bone growth in length were higher in boys, while the values of voluminosity and subcutaneous adipose tissue were higher in girls. Concerning the space of motor variables, there were significant differences in functioning of the mechanism of movement structuring, the mechanism of synergetic regulation, and the mechanism of excitation duration control, which reached higher values in boys, whereas the functioning of the mechanism of tonus regulation showed higher values in girls. These differences generated morphological and motor structures in boys and girls according to age groups analyzed whose relations showed variable level of statistical significance. The youngest and oldest ages showed generalness of the canonical factor structure, as well as the highest significance of participation in the common variance of the two spaces of the variables applied. Between the above ages, i.e. between 4 and 7 years, the relation between morphological characteristics and motor abilities in children decreased, followed by gradual increase. It was monitored by the coefficient of determination between the first pairs of canonical factors in each age category, in boys and girls alike. This relation tended to be higher in boys in all analyzed age categories except for the youngest age where a considerably higher relation was recorded between morphological and motor structure in girls. Such a result could be interpreted by the trend and growth/development level of morphological structure, development of motor structure, development of the central nervous system, as well as by physical activity that is more intensive in boys than in girls.

Key words*: canonical analysis, morphological characteristics, motor abilities, preschool children*

Introduction

Previous studies of morphological structure, and then only including its static aspect that defines dimensionality based on anthropometric measurements, have mostly been based on the samples of subjects that had already achieved a relatively stable stage of growth and development, i.e. adults. There are fewer studies in adolescents, whereas studies in small children are extremely rare. This review will only take in consideration studies conducted in large samples in former Yugoslav republics, without differentiating them according to sex, genetic, ecosocial and other characteristics that may to a minor extent exert specific influence on the generation of morphological structure in humans. The authors that analyzed the structure of morphological dimensions in various, mostly small samples of subjects and variables, without adequate external validity and generalization, while confirming the results previously reported by the cited authors, will not be mentioned.

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The results obtained can be generalized and lead to a conclusion that a four-dimensional model of morphological dimensions can be set in adults, i.e. longitudinal skeleton dimensionality, transverse skeleton dimensionality (joint, distal extremity and head dimensionality), body mass and volume (circular body dimensionality), and subcutaneous adipose tissue[1]. Longitudinal and transverse skeleton dimensionality are frequently united into a single dimension called just skeleton dimensionality or occasionally longitudinal skeleton dimensionality, thus it can be referred to as a three-dimensional model[2,3]. In adolescents, a three-dimensional morphological model has been established, including skeleton dimensionality, body mass and volume, and subcutaneous adipose tissue[4,5], whereas a two-dimensional model of morphological dimensions consisting of skeleton dimensionality and voluminosity, and subcutaneous adipose tissue has been usually applied in small children[6,7].

In the present study, analysis of the motor ability structure was underlain by the results reported by Kurelić et al.[5] in children and adolescents aged 11–17 of both sexes, and by Gredelj, Metikoš, Hošek and Momirović[8] in male adults aged 19–27. These authors have interpreted isolated motor dimensions according to the model of functional mechanisms rather than relative to the motor test contents, i.e. from the phenomenological aspect, as has been usually done before and is still quite frequently encountered. However, the authors emphasize that they had to interpret isolated dimensions according to the structural rather than functional model, due to the lack of appropriate scientific information on the functions of the nervous system regulatory mechanisms and for some methodological reasons. The following dimensions have been identified: factor of the motor unit excitation regulation, factor of the motor unit excitation duration, factor of movement structuring, and factor of functional synergy and tonus regulation. Two dimensions have been established in the space of these factors: factor of energy regulation and factor of movement regulation. Obviously, these authors have started from Bernstein and Anohin's hypotheses (according to Gredelj et al.[8]) and defined these factors predominantly in terms of functional models.

It should be noted that it is simply impossible to define all motor dimensions, their structure and inter-relations by use of these models. These authors themselves designed their studies according to the phenomenological models of the factor structure of motor abilities, of which the one established by Fleishman[9] in his study on large samples is certainly best known and most widely employed. In small children, almost all potential motor abilities are inter-related, thus being frequently referred to as a general motor factor[6], or a two-dimensional model where the first factor actually shows a general pattern, whereas the second one occurs as a single factor of flexibility[10]. The studies mentioned above reveal a certain level of generality in the occurrence of some motor dimensions, along with a variability that results from the subject samples analyzed (e.g., age, sex, size, sampling method, motor experience, genetic potential, etc.), battery of motor tests employed (number, validity and reliability, as well as the level of compliance with standardization of the measuring conditions), and to a lesser extent the procedures used to define motor dimensions, most commonly factor analysis (criterion for factor extraction, methods and techniques of data reduction and transformation of initial solutions).

The term 'growth' generally implies quantitative mass and size increase, and qualitative changes in the child's body shape. 'Development' refers to physiological changes, including changes in the central nervous system, which reflect on the child motor abilities. The former usually implies so-called morphological maturation, i.e. anatomical and physiological alterations, whereas the latter implies functional maturation, i.e. mental (psychological) and motor development. There is close interaction between the processes of growth and development; therefore it is necessary to know not only quantitative levels but also the character of relations between the child morphological and functional development in a particular age and sex.

The growth and development as well as the inter-relations of morphological and motor dimensions show certain regularities that depend on both endogenous and exogenous factors, according to age and sex, and the child physical activity in particular. Attempts at defining these regularities, or at least tendencies, rely on the fact that individual variations among children generate different physical constitution and types of motor abilities. It is necessary to know the regularities that mostly manifest in the form of relations among anthropological dimensions because the efficiency of any motor programs, provided appropriate motor abilities, can only be manifested through the effectors. i.e. muscle, bones and joints. Accordingly, besides the central nervous system and morphological dimensions, the manifestation of motor abilities directly depends on anthropometric characteristics.

The necessity of studying morphological characteristics and motor abilities, or more precise, the man's motor behavior, is obvious not only in everyday circumstances but even more so in specific situations such as sports activities. The need to investigate morphological and motor dimensions is best illustrated by citing Bernstein from 1929 (according to Gurfinkel and Cordo[11]. p. 4):

»*The basic vital properties that exist in the movements of living beings clearly confirm their close analogy to anatomical organs or tissues. Firstly, a live movement reacts and secondly it regularly evolves and involutes. I noted and described the former of these properties as early as 1924 [Bernstein 1924]. Studying the biodynamics of movements involved in cutting with a chisel I was able to show that it is impossible to alter selectively any one given detail in this movement without affecting others. If, for example, the trajectory of the elbow is slightly altered, the form of the trajectory of the hammer is also unavoidably changed; as are the relationships between the velocity of swing and the impact; between the velocities of the wrist and the hammer head; and a whole series of other nuances of the movement.*«

There are many studies on the relations of morphological characteristics and motor abilities in adults, where regression or canonical models were most commonly employed[12], but considerably fewer studies of the type in small children. Results of these studies generally suggest that regular growth and development of morphological dimensions influence to a certain extent regular development of the child general motor ability, while regular development of motor abilities influence regular growth and development of morphological characteristics[13–15]. These findings are in line with the theory of integral development, in kinesiology set by Ismail and Gruber[16].

The problem of defining relations of morphological characteristics and motor abilities can be approached in various ways. One should distinguish between the analytical use of raw data, i.e. manifest variables, to assess anthropometric characteristics and motor abilities on the one hand, and the analysis of structures of linear combinations of particular variables (latent dimensions, factors) or, in this case, morphological characteristics and motor abilities on the other hand. The relations can be analyzed by the methods of factor, regression, discriminative and canonical analysis. All these methods can generate relations defined by structures of the variable spaces analyzed, based on the predictor and criterion variables. Quite frequently, these problems are solved by some of the methods and techniques of factor analysis because the logics of such an analysis says that anthropological dimensions are responsible for covariability of the indicators (variables) applied, and that they can be detected and defined on the basis of this covariability. On doing this, of course, the integral space of predictor and criterion variables, in this case anthropometric and motor variables, is analyzed[7,17,18].

The authors have chosen the canonical correlation model to define relations between the predictor (anthropometric) and criterion (motor) variables[19], which yield the morphological-motor structure on the basis of the predefined linear combinations of variables according to spaces and ranked according the magnitude of contribution to the explanation of their space of variables. Of course, such analyses are planned specifically for the groups of male and female children according to age.

Therefore, the purpose of this study was to point not only to the quantitative values of the child anthropometric characteristics and manifestations of motor abilities, but also to analyze the trend of their relations, expected to indicate the possible regularity during growth and development of preschool male and female children.

Materials and Methods

Subjects

The study sample included 1170 children (565 male and 605 female) aged 4–7.5 decimal years from preschool institutions in three towns in Voivodina, i.e. Novi Sad, Sombor and Bačka Palanka. Study subjects were divided into groups according to age (0.5 decimal years) and sex.

Measures and tests

The set of predictor variables and the set of criterion variables obtained by use of the following tests and measurements were analyzed:

1) anthropometric measurements, where anthropometric characteristics were assessed by the method of International Biological Program (IBP)[20]; and

2) motor tests performed according to Bala's recommendations[21–25].

The sample of anthropometric measures was as follows:

– *for assessment of skeleton dimensionality:*

1) body height (mm),

– *for assessment of voluminosity and subcutaneous adipose tissue:*

2) body weight (0.1 kg),

3) chest girth (mm),

4) midarm girth (relaxed arm girth) (mm),

5) forearm girth (mm),

6) abdominal skinfold (0.1 mm),

7) subscapular skinfold (0.1 mm),

8) triceps skinfold (0.1 mm).

The following test battery was employed for assessment of motor abilities:

– *for assessment of the movement structuring factors:*

1) obstacle course backwards (0.1 s) – restructuring of movement stereotype,

2) standing broad jump (cm), and

3) 20-m dash (0.1 s) – body coordination,

– *for assessment of functional synergy and tonus regulation factors:*

4) arm plate tapping (freq.) – frequency speed, and

5) seated straddle stretch (cm) – flexibility,

– *for assessment of motor unit excitation duration factors:*

6) crossed-arm sit-ups (freq.) – repetitive trunk strength, and

7) bent-arm hang (0.1 s) – static strength of arms and shoulder girdle.

It is observed that the factor of motor unit excitation intensity regulation is missing in this model. In adults, this factor is mostly assessed by the standing broad jump and 20-m dash tests, whereas in the studies of motor abilities in small children it is always integrated in the factor of movement structuring and is manifested as body coordination. Obviously, unlike adults, the majority of preschool children cannot harmoniously coordinate the work of upper and lower extremities, maximally mobilize their motor units and manifest explosive strength on performing these motor tasks.

The mentioned motor tests are briefly described below, while complete standardization of measuring conditions is found in Bala et al.[25]:

1. Obstacle course backwards. The child has to walk backwards on all fours and cover the distance of 10 m, climb the top of Swedish bench and go through the frame of the bench. The task is measured in tenths of second.

2. Arm plate tapping. For fifteen seconds the child has to tap alternately two plates on the tapping board with his dominant hand, while holding the other hand in between the two plates. The result is the number of alternate double hits.

3. Seated straddle stretch. The child sits on the floor, leaning against the wall, in straddle position and bows forward as far as possible. A straight-angle ruler lies down in front of the child and he/she reaches the scale with cm as far as he/she can. The result is the depth of the reach measured in cm.

4. Standing broad jump. The child jumps with both feet from the reverse side of Reuter bounce board onto a carpet, which is marked in cm. The result is the length of the jump in cm.

5. 20 m dash. On command »GO« the child that stands behind the start line has to run 20 m as fast as he/she can to the end of the track (20 m). The children run in pairs. The score is the time of running, measured in tenths of second.

6. Crossed-arm sit-ups. The child lies on his/her back with his/her knees bent and arms crossed on the opposite shoulders. He/she rises into a seated position and returns into the starting position. The instructor's assistant holds the child's feet. The result is the number of correctly executed raises to the seated position (no longer than 60 seconds).

7. Bent arm hang. The child under-grips the bar and holds the pull-up as long as he/she can (chin above the bar). The result is the time of the hold measured in tenths of second.

Data analysis

The basic descriptive statistics parameters were calculated for all variables according to sex and age groups. The significance of differences in the study variables between age categories in male and female children was assessed by multivariate and univariate analysis of variance, and specific differences between pairs of age categories by use of LSD Post Hoc test. The significance of sex differences within each age category was assessed by multifactor analysis of variance.

Canonical correlation analysis[26], where the number of statistically significant canonical correlations was determined according to a more strict criterion ($p \leq 0.01$), was employed to determine relations between anthropometric characteristics and motor abilities.

Results

Anthropometric and motor variables in boys

The basic descriptive statistics parameters of anthropometric and motor variables in male children are shown in Table 1. As the present study was not focused on the analysis of quantitative states, i.e. the levels of growth and development of anthropometric characteristics and development of motor abilities, but on the relations of morphological and motor dimensions in children, the statistics presented in tables will not be interpreted in detail. Yet, some general conclusions should be noted, as follows:

– In male children, the growth and development of anthropometric characteristics is continuous but variable according to age groups. This variability was especially pronounced in the variables for assessment of subcutaneous adipose tissue in all age groups analyzed, their distribution showing statistically significant deviations from normal.
– Quantitative improvement of motor abilities as assessed by arithmetic means of motor variables was manifested in each age group in male children. This improvement was accompanied by different variability in all study variables, those used for assessment of coordination and strength (static and repetitive) in particular.

Analysis of differences between the pairs of age categories in boys showed body height to increase statistically significantly during the study age period, whereas body weight increased but mostly did not reach statistical significance. Other anthropometric characteristics developed at a lower, mostly non-significant rate; it applied to subcutaneous adipose tissue in particular.

In boys, differences in motor variables among age categories were statistically significant in younger age groups, whereas in older age groups (preschool) the difference turned non-significant, except for the variables for assessment of flexibility (seated straddle stretch) and strength (bent-arm hang and crossed-arm sit-ups), which showed a relatively poor development of these abilities during the study period. It is concluded that there is a continuous favorable trend in the development of all motor variables, i.e. motor abilities analyzed in male preschool children.

Anthropometric and motor variables in girls

The basic descriptive statistics parameters of anthropometric and motor variables in female children are shown in Table 2, indicating the following:

-In female children, the growth and development of anthropometric characteristics is also continuous but variable according to age groups. This variability was especially pronounced in the variables for assessment of subcutaneous adipose tissue in all age groups analyzed, and in the chest girth variable in the 5–5.5 and 6.5–7 age groups, their distributions showing statistically significant deviations from normal.

TABLE 1
DESCRIPTIVE STATISTICS (mean ± SD) OF ANTHROPOMETRIC AND MOTOR VARIABLES IN MALE CHILDREN (N=565)

Years	1 (4–4.5)	2 (4.51–5)		3 (5.01–5.5)		4 (5.51–6)		5 (6.01–6.5)		6 (6.51–7)		7 (7.01–7.5)	
Variable	N=54	N=64		N=98		N=115		N=96		N=96		N=42	
	Mean±SD	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p
Body height (cm)	108.5±4.3	111.8±5.1	a	115.1±5.1	a	117.9±4.9	a	121.7±5.1	a	125.1±5.5	a	128.0±5.5	a
Body weight (kg)	18.4±2.7	19.9±3.7		20.8±3.2		22.3±3.8	a	24.5±4.8	a	26.1±5.6	b	27.2±4.8	
Chest girth (cm)	54.6±3.0	56.0±3.4		56.4±3.0		57.3±3.6		59.2±4.6	a	60.1±5.5		60.9±4.4	
Midarm girth (cm)	17.6±1.7	17.9±2.2		18.4±1.8		18.8±2.0		19.4±2.5	b	19.9±2.6		20.5±2.5	
Forearm girth (cm)	17.3±1.2	17.5±1.6		17.8±1.2		18.2±1.4	b	18.8±1.6	b	19.1±1.8		19.6±2.1	
Abdominal skinfold (mm)	6.5±3.4	6.5±4.1		6.4±3.2		7.3±4.9		7.6±5.3		7.7±5.1		8.1±4.6	
Subscapular skinfold (mm)	5.9±1.9	6.0±2.3		6.0±2.0		6.1±2.6		6.8±3.6		7.0±4.0		6.8±3.1	
Triceps skinfold (mm)	8.0±2.1	8.4±2.8		8.4±2.7		8.6±3.1		8.9±3.5		9.4±4.3		9.4±3.2	
20-m dash# (s)	6.3±0.8	6.0±0.7	b	5.6±0.7	a	5.2±0.5	a	5.1±0.5	b	4.8±0.5	b	4.7±0.6	
Obstacle course backwards# (s)	41.4±14.3	39.3±14.6		33.2±10.9	a	28.9±9.2	a	26.6±9.8		24.3±9.2		21.1±6.8	
Arm plate tapping (freq.)	11.3±3.0	13.3±2.7	a	14.0±3.0		15.2±3.1	b	16.7±3.4	a	17.6±3.3	b	18.7±3.7	
Seated straddle stretch (cm)	32.7±6.4	33.7±7.4		33.4±6.4	b	35.9±6.3		37.0±6.9		37.5±7.3		38.1±8.6	
Standing broad jump (cm)	83.6±18.4	90.7±15.4	b	100.9±19.1	a	111.2±16.9	a	117.6±18.2	a	121.9±16.3		131.4±18.6	a
Bent-arm hang (s)	5.2±5.1	8.2±7.6		8.7±7.6		11.7±11.6		13.4±12.7		16.4±15.2		20.5±14.6	b
Crossed-arm sit-ups (freq.)	10.2±7.9	12.1±7.8		17.1±9.0	a	19.7±8.9	b	22.1±8.1	b	24.0±8.3		26.5±9.4	

p – significance of difference *vs.* previous age group ([a]$p<0.01$, [b]$p<0.05$), #variable with opposite metric orientation

-Improved results on the tests assessing motor abilities were also recorded in each age group of female children. This improvement was also accompanied by different variability in all variables, in particular those used for assessment of coordination (obstacle course backwards) and static strength (bent-arm hang) in younger age groups, and of running speed (20-m dash) in older age groups (6.5–7 years).

Differences in anthropometric characteristics between each consecutive age categories in female children were comparable to those recorded in male children. Differences in the motor variables analyzed among particular age categories of female children were very similar to those recorded in male children. Of course, this refers to differences, not quantitative levels in male and female children.

Differences of anthropometric and motor variables between boys and girls

The significance of differences in anthropometric characteristics between male and female children within each age category was tested by multifactor analysis of variance and results are presented in Table 3.

The following statistically significant sex differences were identified:

- female children from the youngest age group had significantly greater amount of subcutaneous adipose tissue than male children; there was no significant difference in other anthropometric characteristics. In the next half- -year category, a significant increase in body weight and thorax development was recorded in male children, without any significant difference in other characteristics;
- female children aged 5–6 years showed a statistically significantly greater amount of subcutaneous adipose tissue on the body segments analyzed, except of the abdomen. This variable also yielded quantitative differences in favor of female children, however, without statistical significance. Similar observations were also recorded for other variables that indicated quantitatively greater values of body height, body weight, chest girth and forearm girth in male children. Female children had higher values of midarm girth, which was attributed to the significantly greater amounts of subcutaneous adipose tissue;
- in the 6–7.5 age groups, statistically significantly greater values of body height, chest girth and forearm girth

TABLE 2
DESCRIPTIVE STATISTICS (mean ± SD) OF ANTHROPOMETRIC AND MOTOR VARIABLES IN FEMALE CHILDREN (N=605)

Years	1 (4–4.5)	2 (4.51–5)		3 (5.01–5.5)		4 (5.51–6)		5 (6.01–6.5)		6 (6.51–7)		7 (7.01–7.5)	
Variable	N=46	N=84		N=79		N=104		N=122		N=129		N=41	
	Mean±SD	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p
Body height (cm)	107.0±4.8	110.2±4.1	a	115.1±5.1	a	117.6±5.4	a	120.0±5.7	a	123.2±6.1	a	125.3±5.8	b
Body weight (kg)	18.4±3.3	19.1±2.6		20.5±2.6	b	22.1±3.5	a	22.8±4.2		24.8±5.7	a	25.4±4.4	
Chest girth (cm)	53.9±3.8	54.3±2.7		55.6±5.2		56.5±4.0		57.0±4.0		57.7±5.8		58.5±4.3	
Midarm girth (cm)	18.2±1.9	18.2±1.8		18.6±1.6		19.3±2.1	b	19.3±2.1		20.0±2.2	a	20.1±2.2	
Forearm girth (cm)	17.4±1.3	17.4±1.0		17.7±1.1		18.1±1.2	b	18.1±1.3		18.4±1.6	b	18.6±1.3	
Abdominal skinfold (mm)	7.9±3.5	7.5±3.9		7.2±3.7		8.4±4.7		8.1±4.7		8.5±5.3		8.7±4.2	
Subscapular skinfold (mm)	7.1±2.1	6.7±2.2		6.8±3.0		7.5±3.2		7.1±2.7		7.2±3.4		8.0±3.4	
Triceps skinfold (mm)	9.5±2.2	9.3±2.9		9.3±2.4		10.1±3.0		9.7±3.2		9.9±3.6		10.6±3.7	
20-m dash# (s)	6.5±1.0	6.2±0.8	a	5.7±0.7	a	5.5±0.7	b	5.2±0.5	a	5.2±0.7		5.1±0.5	
Obstacle course backwards# (s)	54.1±23.3	42.0±14.8	a	38.3±12.2		32.9±10.9	a	30.1±9.9		29.3±10.0		28.5±11.3	
Arm plate tapping (freq.)	11.5±3.1	12.4±2.7		14.0±2.6	a	15.5±3.4	a	15.8±2.8		17.0±3.1	a	18.0±2.8	b
Seated straddle stretch (cm)	36.5±5.7	37.7±6.1		38.2±6.0		41.4±7.6	a	41.9±7.6		43.0±7.1		42.9±9.7	
Standing broad jump (cm)	75.5±16.5	85.6±17.5	a	92.7±15.2	b	101.6±18.7	a	108.1±16.0	a	113.6±18.6	a	116.8±18.9	
Bent-arm hang (s)	5.6±6.0	7.4±8.1		8.4±6.4		10.8±9.8		13.8±10.7	b	15.6±12.0		12.2±9.2	b
Crossed-arm sit-ups (freq.)	13.0±8.9	15.1±8.4		18.9±8.7	b	20.4±9.5		23.9±9.7	a	24.7±8.8		24.8±10.5	

p – significance of difference *vs.* previous age group ([a]p<0.01, [b]p<0.05), [#]variable with opposite metric orientation

were only recorded in male children. Interestingly enough, in male children body weight was significantly greater only in the 6–6.6 age group but not later;

– a statistically significant sex difference in the performance of motor tests applied was found in all age groups;

– in the youngest age group (4–4.5 years), significant difference was only recorded in the whole body coordination (obstacle course backwards) in favor of male children, whereas female children showed significantly better flexibility;

– in the next half-year age group, male children were superior to female children in performing all motor tests, but the difference did not reach statistical significance. However, female children were statistically significantly better in performing the test for assessment of flexibility and in repetitive strength of the trunk;

– in the 5–6 age group, male children were superior in performing motor tests for assessment of coordination and running speed (obstacle course backwards, standing broad jump and 20-m dash), and female children only in performing the test for assessment of flexibility (seated straddle stretch);

– a very similar pattern was recorded in the 6–7.5 age categories. Male children were superior again in performing the tests as in previous age categories, and in the oldest age category also in performing the test assessing the static strength of arms and shoulder girdle (bent-arm hang). Female children continued to be superior in performing the test assessing flexibility.

These analyses of the significance of sex differences in anthropometric and motor variables are useful for identification and interpretation of relations between these two sets of variables.

Relations of anthropometric and motor variables in male children

In the youngest group of male children (4–4.5 years) there were no statistically significant canonical correlations, suggesting that their motor development had not yet been defined by clear effector function, i.e. by body and extremity characteristics (Table 4).

In male children aged 4.5–5, only one statistically significant canonical correlation (p=0.00) was recorded, yielded by the variables assessing body mass and volume in the morphological space, and the variables assessing

TABLE 3
BIOMOTOR SEX DIFFERENCES ACCORDING TO AGE GROUPS (N=1170)

Years	1 (4–4.5)		2 (4.51–5)		3 (5.01–5.5)		4 (5.51–6)		5 (6.01–6.5)		6 (6.51–7)		7 (7.01–7.5)	
Variable	F	p	F	p	F	p	F	p	F	p	F	p	F	p
Body height (mm)	2.96		4.71	B^b	0.03		0.31		5.23	B^b	5.61	B^b	4.82	B^b
Body weight (0.1 kg)	0.01		2.03		0.43		0.11		7.53	B^a	2.59		3.38	
Chest girth (mm)	1.17		11.57	B^a	1.52		2.50		13.97	B^a	9.51	B^a	6.74	B^a
Midarm girth (mm)	2.77		0.68		0.51		2.77		0.10		0.05		0.64	
Forearm girth (mm)	0.23		0.23		0.27		1.09		12.69	B^a	10.89	B^a	6.94	B^a
Abdominal skinfold (0.1 mm)	3.83	G^b	1.94		2.10		2.88		0.48		1.52		0.49	
Subscapular skinfold (0.1 mm)	9.29	G^a	3.53		5.01		12.07	G^a	0.56		0.19		2.39	
Triceps skinfold (0.1 mm)	10.84	G^a	3.56		5.07		13.05	G^a	3.23		1.14		2.25	
20-m dash# (0.1 s)	1.15		0.80		3.95	B^b	13.68	B^a	8.24	B^a	16.43	B^a	5.59	B^b
Obstacle course backwards# (0.1 s)	11.45	B^a	0.93		8.57	B^a	8.66	B^a	6.65	B^a	14.95	B^a	13.14	B^a
Arm plate tapping (freq.)	0.20		2.92		0.03		0.43		4.59	B^b	1.94		0.69	
Seated straddle stretch (cm)	9.87	G^a	12.72	G^a	24.58	G^a	33.51	G^a	24.14	G^a	34.49	G^a	5.72	G^b
Standing broad jump (cm)	3.32		3.18		11.34	B^a	16.02	B^a	16.59	B^a	11.02	B^a	12.45	B^a
Bent-arm hang (0.1 s)	0.29		0.18		0.08		0.37		0.07		0.15		9.50	B^a
Crossed-arm sit-ups (freq.)	2.54		4.97	G^b	1.67		0.28		2.15		0.33		0.29	

B – boys, G – girls, $^a p<0.01$, $^b p<0.05$, #variable with opposite metric orientation

TABLE 4
CANONICAL CORRELATION ANALYSES BETWEEN ANTHROPOMETRIC AND MOTOR VARIABLES IN MALE CHILDREN

Years	4–4.5	4.51–5	5.01–5.5		5.51–6	6.01–6.5		6.51–7	7.01–7.5
Variable	CAN1	CAN1	CAN1	CAN2	CAN1	CAN1	CAN2	CAN1	CAN1
Body height (mm)	0.38	0.31	0.67	0.20	–0.79	0.15	0.66	–0.46	0.31
Body weight (0.1 kg)	0.47	0.62	0.35	0.55	–0.54	–0.29	0.84	–0.66	0.02
Chest girth (mm)	0.45	0.63	0.33	0.32	–0.28	–0.28	0.82	–0.67	–0.18
Midarm girth (mm)	0.54	0.58	0.09	0.58	–0.32	–0.54	0.57	–0.61	–0.09
Forearm girth (mm)	0.24	0.72	0.12	0.46	–0.23	–0.43	0.61	–0.59	–0.56
Abdominal skinfold (0.1 mm)	0.44	0.34	–0.29	0.31	–0.08	–0.79	0.47	–0.74	–0.30
Subscapular skinfold (0.1 mm)	0.47	0.26	–0.26	0.29	–0.22	–0.58	0.70	–0.83	–0.31
Triceps skinfold (0.1 mm)	0.70	0.20	–0.31	0.43	–0.07	–0.68	0.58	–0.84	–0.04
20-m dash# (0.1 s)	0.05	–0.30	–0.45	–0.56	0.01	–0.75	–0.29	–0.65	–0.86
Obstacle course backwards# (0.1 s)	–0.01	–0.10	–0.12	–0.05	–0.39	–0.43	0.17	–0.78	0.01
Arm plate tapping (freq.)	–0.21	0.21	0.01	0.62	–0.32	0.49	0.17	0.13	–0.37
Seated straddle stretch (cm)	0.32	–0.10	0.60	0.15	–0.71	0.18	0.68	0.17	0.13
Standing broad jump (cm)	0.13	0.72	0.72	0.01	–0.01	0.88	–0.01	0.75	0.52
Bent-arm hang (0.1 s)	–0.53	–0.41	0.19	–0.23	0.25	0.56	–0.40	0.55	0.13
Crossed-arm sit-ups (freq.)	–0.56	0.44	0.35	0.20	0.20	0.30	–0.09	0.16	0.00
Can R	0.69	0.64^a	0.59^a	0.47^a	0.60^a	0.61^a	0.55^a	0.73^a	0.92^a
Can R^2	0.47	0.41^a	0.35^a	0.22^a	0.36^a	0.37^a	0.30^a	0.54^a	0.84^a

CAN – structure of canonic variables, Can R – canonic correlation coefficient, Can R^2 – coefficient of canonical determination, $^a p<0.01$

strength (standing broad jump, bent-arm hang and crossed-arm sit-ups) in the motor space. The structure of the first pair of canonical factors was explained by 41% of common variability. There were positive relations of body mass and volume, with greater body weight but a slight increase in subcutaneous adipose tissue on the abdomen, and the variables assessing body coordination with explosive strength of lower extremities and repetitive strength of the trunk. The same morphological structure showed negative relation with repetitive strength (bent-arm hang). It is a logical result, considering that greater muscle mass (that is indirectly assessed by the measures of body part circumferences) is necessary for efficient performance of strength tests, explosive and repetitive strength in particular. It is likely to represent the overall soft tissue growth and development without marked adipose tissue increase in male children at this age.

In male children aged 5.01–5.50 decimal years, two statistically significant canonical correlations (p=0.00) were identified. The first pair of canonical factors explained 35% of common variance, and the second pair explained only 22% of the remaining space. The first canonical factor was significantly defined by the variables generally taken as basic ones for assessment of the child growth and development, i.e. the variables of body height, body weight and chest girth. Such a morphological structure showed positive correlation with the structure of canonical factor significantly defined by the motor variables of 20-m dash, seated straddle stretch, standing broad jump, and to a minor extent crossed-arm sit-ups. These very motor variables greatly depend on the subject's longitudinal measures because 'long levers', either upper or lower extremities, facilitate performance of these tests. It is manifested either as longer stride on running, longer distance at long jump, or as longer reach when the length of the arms and trunk are crucial. The relation of the second canonical pair was defined by the variables assessing body mass and volume and subcutaneous adipose tissue, and the motor variables of 20-m dash and arm plate tapping.

In male children aged 5.51–6.0 decimal years, there was only one statistically significant canonical correlation (p=0.00). Canonical factor in the space of anthropometric variables was significantly defined by the variables of body height, body weight and midarm girth, and motor factor by the variables of seated straddle stretch, obstacle course backwards and arm plate tapping. Explaining 36% of common variability, this pair of canonical factors indicated the morphological structure to have a significant favorable effect on the motor structure in the segment of abilities as manifested by seated straddle stretch and arm plate tapping, and unfavorable effect on the abilities as manifested by obstacle course backwards. It clearly suggested that taller boys, also being relatively heavier, have greater reach on performing the test assessing flexibility because of their longer levers, upper extremities and trunk in particular. In addition, such a constitution of male children hampered their performance of the test assessing coordination due to more difficult manipulation with their longer extremities, especially on crawling through the Swedish bench frame, thus posing a difficulty on performing this part of the test.

In the age group of 6.01–6.5 decimal years, two statistically significant canonical correlations were identified. The first (p=0.00) was defined by the canonical factor structurally predominated by voluminosity and subcutaneous adipose tissue, and the canonical factor of general motoricity except for flexibility. Explaining 37% of the common variability of the two sets of variables, the structures of the first pair of canonical factors pointed to negative relation, i.e. a relation that could explain poorer motoricity by increased voluminosity on the account of subcutaneous adipose tissue in male children, and *vice versa*. The second statistically significant correlation (p=0.01) was explained by the second pair of canonical factors, which explained the remaining 30% of common variance. The factor from morphological space was defined by all variables, suggesting a general morphological factor, whereas the factor from the space of motor variables had a significant structure predominantly defined by the positively oriented variable of seated straddle stretch and negatively by the variable of bent-arm hang. These structures indicate that the general growth of boys at this age favors the manifestation of flexibility (as assessed by the test applied), while significantly hampering motor tasks that predominantly require static strength of the arms and shoulder girdle. This could be explained by greater body weight, either efficient or ballast mass, which is an interfering factor for successful performance of the bent-arm hang test.

Only one statistically significant canonical correlation (p=0.00) was identified in the group of male children aged 6.51–7.0 decimal years, which explained 54% of the common variance of the two sets of variables. A general morphological factor was observed again in the morphological space, predominating in the variables assessing subcutaneous adipose tissue. The space of motor variables was defined by the canonical factor structurally predominated by the variables of obstacle course backwards, 20-m dash, standing broad jump and bent-arm hang. There was overt negative correlation between the morphological and motor structures, mostly due to the greater amount of subcutaneous adipose tissue in this age group.

The oldest group of male children were characterized by only one statistically significant canonical correlation (p=0.00), which explained 84% of the common variance of the sets of variables analyzed. Canonical factor from the morphological space was mostly defined by the positively oriented variable of body height and negatively oriented variables of forearm girth, abdominal skinfold and subscapular skinfold. Considering motor space, the variables of 20-m dash and standing broad jump with positive orientation and the variable of arm plate tapping with negative orientation yielded highest qualitative contribution to the factor structure. The relation of this pair of canonical factors indicates that taller and thinner boys can better perform long jump and run faster, but have poorer results in alternative arm movements; and *vice versa*, shorter and sturdy boys are less successful in running and jumping, but achieve better results in the arm plate tapping test. These relations could probably be explained by some other factors that were beyond the scope of the present study (e.g., previous motor experience, neurological and functional development at this age, mental development, etc.).

TABLE 5
CANONICAL CORRELATION ANALYSES BETWEEN ANTHROPOMETRIC AND MOTOR VARIABLES IN FEMALE CHILDREN

Years	4–4.5	4.51–5	5.01–5.5	5.51–6		6.01–6.5		6.51–7		7.01–7.5
Variable	CAN1	CAN1	CAN1	CAN1	CAN2	CAN1	CAN2	CAN1	CAN2	CAN1
Body height (mm)	0.35	0.00	–0.28	0.60	–0.20	0.65	–0.23	0.39	–0.61	0.50
Body weight (0.1 kg)	0.83	–0.45	–0.35	0.10	–0.63	0.41	–0.44	0.67	–0.35	–0.01
Chest girth (mm)	0.86	–0.37	–0.36	–0.06	–0.64	0.37	–0.40	0.70	–0.06	0.00
Midarm girth (mm)	0.78	–0.48	0.00	–0.11	–0.57	0.03	0.01	0.67	0.15	–0.43
Forearm girth (mm)	0.86	–0.43	–0.02	0.06	–0.42	0.22	–0.24	0.66	–0.37	0.02
Abdominal skinfold (0.1 mm)	0.90	–0.72	–0.61	–0.46	–0.39	–0.14	–0.52	0.95	–0.01	–0.34
Subscapular skinfold (0.1 mm)	0.79	–0.67	–0.54	–0.49	–0.48	–0.23	–0.43	0.89	0.20	–0.14
Triceps skinfold (0.1 mm)	0.72	–0.84	–0.62	–0.50	–0.20	–0.22	–0.54	0.77	0.15	–0.12
20-m dash[#] (0.1 s)	–0.10	–0.61	–0.41	–0.56	–0.20	–0.45	–0.55	0.48	0.30	–0.04
Obstacle course backwards[#] (0.1 s)	0.58	–0.72	–0.30	–0.43	–0.76	–0.48	0.02	0.34	0.56	–0.45
Arm plate tapping (freq.)	0.51	0.13	–0.27	0.19	0.62	0.33	–0.49	0.02	–0.77	0.86
Seated straddle stretch (cm)	0.07	–0.17	–0.03	0.64	–0.32	0.61	–0.24	0.29	–0.02	0.08
Standing broad jump (cm)	–0.08	0.72	0.68	0.74	0.41	0.84	0.26	–0.63	–0.33	0.51
Bent-arm hang (0.1 s)	–0.37	0.50	0.47	0.40	0.48	0.19	0.57	–0.81	0.05	0.47
Crossed-arm sit-ups (freq.)	0.12	0.09	0.32	0.67	–0.03	0.44	0.39	–0.27	–0.68	0.08
Can R	0.85[a]	0.60	0.52	0.54[a]	0.52[a]	0.60[a]	0.54[a]	0.56[a]	0.52[a]	0.87[a]
Can R^2	0.73[a]	0.36	0.27	0.30	0.27[a]	0.36[a]	0.30[a]	0.31[a]	0.27[a]	0.76[a]

CAN – structure of canonic variables, Can R – canonic correlation coefficient, Can R^2 – coefficient of canonical determination, [a]$p<0.01$

Relations of anthropometric and motor variables in female children

In the group of female children aged 4–4.5 years, one statistically significant canonical correlation (p=0.00) was identified (Table 5). The first and only significant pair of canonical factors defined the relation between the morphological and motor spaces of study variables to a surprisingly high extent (73%). The structure of the canonical factor of the morphological space was expressed by a combination of all anthropometric variables, with the least projection of the body height variable. Accordingly, this canonical factor could be defined as a general factor of growth and development in female children of this age. Concerning motor space, the variables of obstacle course backwards, arm plate tapping and bent-arm hang had highest projections on the canonical factor. Thus, the first and third variable showed negative correlation, and the second one positive correlation with morphological factor. These findings indicated the girls with lower soft tissue dimensionality (volume, body weight and subcutaneous adipose tissue) and to a lesser extent lower longitudinal dimensionality to achieve better results in the tests assessing whole body coordination and static strength of the arms and shoulder girdle. It appears quite logical since body height, and thus longer upper and lower extremities, interfere with efficient, rapid and coordinated activity of all body parts on performing the motor task of obstacle course backwards, as well as on jumping over the bounce board and crawling through the Swedish bench frame. The generally greater dimensionality of all morphological characteristics is a hampering factor on performing bent-arm hang, especially considering the fact that the arm and shoulder girdle muscle strength is rather poorly developed in female children of this age. On performing the test assessing the speed of alternate movements (arm plate tapping), the more pronounced morphological growth and development, longer arms in taller girls in particular, along with greater active muscle mass and voluminosity contributed to a more efficient performance of this motor task.

No statistically significant canonical correlations were recorded in the groups of female children aged 4.51–5.0 and 5.01–5.5 decimal years, suggesting the motor structure to be relatively independent of the morphological structure in female children of these age groups. This poses the need of additional studies in these age groups in order to determine whether this age period is really characterized by motor functioning independent of morphological structure in female children, or the respective result was due to the method of subject sampling, or it could be ascribed to some methodological drawbacks of the present study.

In female children aged 5.51–6.0 decimal years, two statistically significant correlations were obtained (p= 0.00). From morphological space, the first factor was predominantly but negatively defined by the variable of body height and all variables assessing subcutaneous adipose tissue (abdominal skinfold, subscapular skinfold, and triceps skinfold). From motor space, the first canonical factor was explained by all variables except for the variable of arm plate tapping. The girls from this age group were taller and thus of a more delicate morphological structure, with less subcutaneous adipose tissue, and showed better performance on all motor tasks, with the exception of hand tapping where such a constitution is not crucial for efficient performance. The second pair of canonical factors explained 27% of the remaining common variability (residual variability upon extraction of the first pair of canonical factors). The first factor from the second pair of canonical factors was defined by all variables except for body height and triceps skinfold. In the criterion set of the second pair, a canonical factor was identified with a structure defined by the variables of obstacle course backwards, arm plate tapping, bent-arm hang, standing broad jump, and to a lesser extent and less negatively by the variable of seated straddle stretch. The second pair of canonical factors showed negative relations, with the exception of flexibility. This feature clearly identified the subjects with greater soft tissue dimensionality, in particular subcutaneous adipose tissue on the back and abdomen, as ballast mass; due to such a constitution, these subjects were less efficient in performing most of the motor tasks. The exception was the variable assessing flexibility where, as in male children alike, the increased body voluminosity and greater amounts of subcutaneous adipose tissue were confirmed to cause no interference with efficient performance.

In the group of female children aged 6.01–6.5 decimal years, two statistically significant canonical correlations were identified again (p=0.00). The first factor from the first pair of canonical factors explained 36% of common variability and was predominantly saturated by the basic variables for assessment of the child growth and development, i.e. body height, body mass and chest girth, whereas the factor from the set of motor variables was predominantly defined by all variables except for bent arm hang. This relation of the first pair of canonical factors indicates the girls with a constitution in adults defined as athletic (mesomorphic) type to be more efficient in performing all motor tasks. The second canonical correlation showed the same level of statistical significance as the first one (p=0.00) and explained the remaining 30% of variability. The morphological set of factors defining the structure was predominated by the variables for assessment of subcutaneous adipose tissue, body weight and chest girth. The structure of motor factors was mostly defined by strength (bent-arm hang, crossed-arm sit-ups) as well as by running speed and speed of alternate arm movements (20-m dash and arm plate tapping). The relation of the second pair of canonical factors clearly showed the increased amount of subcutaneous adipose tissue in combination with chest girth, which is probably increased due to adipose tissue accumulation, had unfavorable impact on performing the tests for assessment of strength (repetitive and static) and speed. It was confirmed again that such a 'massive constitution' of these study subjects obviously had favorable effect on their efficient performance of the test assessing the speed of alternate movements.

Two statistically significant canonical correlations (p=0.00) were also identified in our female subjects aged 6.51–7.0 decimal years. The first canonical factor from the set of anthropometric variables included all variables and could therefore be considered a general factor of growth and development in female children of this age. The respective pair of canonical factors from the motor space was defined by all variables, to a lesser extent by the variable assessing flexibility, but not by the variable of arm plate tapping. In this age group, the girls with high dimensionality of all morphological characteristics and a decisively increased amount of adipose tissue tended to show poorer performance on the tests assessing strength and on body manipulation either through obstacle course backwards or running speed. This relation explained 31% of the common variability of the two sets of variables. The morphological factor from the second pair of canonical factors was predominantly saturated by the variables of body height, body weight and forearm girth, i.e. the variables that are frequently taken as a minimal indicator of the child growth and development. Other variables did not contribute invariably to the definition of this factor. The respective factor from the motor set showed a structure that was predominantly composed of all motor variables, with the exception of the variables assessing static strength (bent-arm hang) and flexibility (seated straddle stretch). The relation of this pair of canonical factors was explained by 27% of the remaining variability and indicated the girls of delicate build, small mass and low muscle mass of upper extremities to be less efficient on performing most of the motor tests. And *vice versa,* the girls of stronger build and lower amount of subcutaneous adipose tissue exhibited higher abilities on performing the majority of the motor tests applied.

Only one statistically significant correlation (p=0.00) was identified in the group of female children aged 7.01–7.5 decimal years, explaining quite a large proportion, i.e. about 76% of common variability. Concerning the anthropometric set of variables, the factor was predominated by the variables of body height, midarm girth and abdominal skinfold. As for the motor space, the structure of the canonical factor was predominated by the variables of arm plate tapping, standing broad jump, bent-arm hang and obstacle course backwards. The resulting relation indicated the girls with greater body height but lower upper extremity voluminosity and lower adipose tissue, abdominal in particular, to be more efficient on performing the tests assessing alternate arm movements, body coordination, and explosive and static strength of the arms and shoulder girdle.

Discussion and Conclusion

The results obtained indicated the growth and development of anthropometric characteristics in male and female children to be continuous but differently variable according to age groups. This variability was especially pronounced in the variables for subcutaneous tissue assessment. In general, in older age groups male children showed significantly higher values in the variables of body height, chest girth and forearm girth, whereas female children had significantly greater amount of subcutaneous adipose tissue in younger age groups.

Quantitative improvement of motor abilities was observed in each group of both male and female children. This improvement was also accompanied by different variability in all variables, in particular those for coordination and strength (static and repetitive) assessment. Male children were generally found to have significantly better coordination (as assessed by the tests of obstacle course backwards, standing broad jump and 20-m dash) in all age periods analyzed. It may seem strange to use the latter two variables rather than running speed and explosive strength of lower extremities (as used in adults) for assessment of coordination in children. However, in children of these age groups, these variables show a more favorable pattern for coordination assessment just because of the as yet undifferentiated primary motor abilities, since the respective motor tests primarily require coordinated performance of the movements and motion needed, which belongs to the domain of the informatics component of child motoricity. Therefore, the magnitude of the energy component that the child has to manifest by maximal excitation of motor units in both cases, can only be expressed when the entire task structure has been successfully mastered. We observed a pronounced static strength of the arms and shoulder girdle over the age periods analyzed in all children, and repetitive strength in female children from younger age groups and in male children from the oldest age group. Female children showed a statistically significantly better performance in the manifestation of flexibility in all age groups.

Analysis of the results collected to date from the aspect of the neurophysiologic mechanisms defined in studies conducted in older children and adolescents[5], and even more extensively in adults[8], points to a conclusion that the function of the mechanism of movement structuring is superior in male children, as manifested through the motor abilities of body coordination (standing broad jump and 20-m dash) and restructuring of movement stereotypes (obstacle course backwards), and the mechanisms for regulation of excitation duration and motor units (bent-arm hang). Female children showed superior functioning of the mechanisms for synergy regulation and tonus regulation. However, a part of this mechanism referring to synergy regulation and manifesting as the speed of frequency (arm plate tapping) was pronounced in younger age groups in female children and in older age groups in male children. The part referring to tonus regulation (seated straddle stretch) was constantly and significantly more pronounced in female children across all age groups.

In the youngest group of male children, there was no statistically significant relation of the morphological and motor structure. In female children, a significant general morphological structure, i.e. general morphological growth and development, was found on predicting motor structure, which was also associated with the mechanism of movement structuring (through restructuring of the movement stereotype) and mechanism of synergy regulation (through the speed of frequency), as well as the mechanism of the regulation of excitation duration (through static strength of the arms and shoulder girdle). However, this relation was negative due to the higher level of soft tissue development, manifested by greater body girths and greater amount of subcutaneous adipose tissue and lower longitudinal development of bone tissue, as recorded by body height. The result indicating that such a morphological structure would better manifest the speed of frequency (arm plate tapping) could be explained by the development of the central nervous system rather than the structure observed. According to our study results, this period is very important in female children because the greater biological growth and development that are mostly manifested just through the morphological structure exert unfavorable effects on their motor structure and motor behavior. These girls are 'clumsier' and weaker in comparison with those with a lower amount of soft tissue and greater body height.

Subsequent morphological development revealed a discrepancy between the growth of soft and bone tissue in both male and female children. In male children, harmonious and general growth is mostly observed in the usual school age, i.e. at age 6–7, and in female children at age 6.5–7. According to the results obtained with the canonical model of relation defining, unlike female children, motor development in male children is not characterized by general development. In female children, the unity of motor space, i.e. of the mechanisms for movement and for energy regulation, was most pronounced at age 5.5–6.5.

The results obtained on the relations between morphological and motor structures defined as canonical factors generally suggest that voluminosity deriving mostly from subcutaneous adipose tissue acts as an interfering factor in the functioning of the mechanisms for movement structuring, synergy regulation and energy regulation in children. Normal growth of bone tissue, longitudinal in particular, accompanied by a proportional pattern of body weight and soft tissue volume (which in turn still implies greater amount of the muscle tissue and lower amount of adipose tissue), enables regular functioning of the entire nervous system and better functioning of all components responsible for the child motor behavior. Such a behavior implies harmonious functioning of the mechanism of movement regulation, along with actual functioning of the mechanism of energy regulation, with solving the motor problems appropriate for the respective age group.

The magnitude of relations between the morphological and motor structures during the study age periods in male (Table 4) and female (Table 5) children can be perceived from the coefficients of canonical correlations between the respective pairs of canonical factors. Of course, it refers to statistically significant coefficients, while the coefficient of the first pairs in each age group of male and female children should be analyzed to follow the trend of relations of these two anthropological spaces because this relation is best explained by these pairs. The association is more suitable to define by the coefficients of determination, i.e. percentage of the explained proportion of common variability in the morphological and motor spaces. However, it should be noted that it is not assessment of the relation of the complete sets of anthropometric and motor variables, but only of the first pair of canonical factors which explain this relation to the greatest extent but not completely.

Obviously there was quite a high association of morphological and motor structures in the youngest age group of male children; this relation was explainable by about 47% of common variability. This finding suggested that motor development, and thus motor behavior in male children was to a considerable extent defined by both morphological growth and development. After the age of 4.5, this relation subsided, to increase in the 6.5–7 age group and reach peak at age 7. When analyzing the respective pairs of canonical factors, this finding indicates the relation to predominantly depend on the general and harmonious morphological growth and development, along with improved but not general development of motoricity in male children (Table 4).

A similar trend of relations between the morphological and motor structures was also observed in female children (Table 5). Yet, female children showed a considerably higher relation explaining as much as 73% of this association, indicating that motor development depended on morphological structure to a greater extent in female than in male children. This relation showed additional decrease in female children, to rise abruptly after age 7, when it explained a percentage of common variability (76%) of the most important pairs of canonical factors that approached the percentage recorded in the youngest age group (73%).

Generally, the relation between the morphological and motor structures was higher in male children in all age groups analyzed except for the youngest one, which showed a considerably greater level of association in female children. This result was attributed to the trend and level of growth and development of morphological structure, and development of the motor structure (analyzed on the basis of anthropometric and motor variables), development of the central nervous system, as well as to physical activity that was more pronounced in male than in female children.

Although the present study included children samples that yielded a transverse survey of the anthropometric characteristics and motor abilities in children aged 4–7.5 years, the results obtained can be taken as indicators of changes in function of the respective age span. It is justified by the higher number of time points, i.e. samples of children divided according to half-year age groups and relatively representative samples of male and female children from the respective populations of the three Vojvodina towns. Of course, the results presented can be additionally tested in other, larger samples of children, and age groups can be further subdivided according to even shorter time intervals (e.g., two months) because the first author's experience shows motor development to proceed faster than morphological development in preschool children, especially if supported by physical activity. The rate of this development in preschool children is such that the child can develop motoricity in 1–2 months to such an extent which in school children takes a year. This issue is of interest not only for professionals in biological, medical and educational disciplines, but also for kinesiologists to design appropriate planning and control of training processes on using various kinesiologic activities for development of motor behavior or in sports activities, in so-called 'child sports' implying very early specialization of talented children in a particular sports discipline. Quite different is the issue of justifiability of such an approach to early specialization relative to the development of general motoricity in small children and their biological, mental and social development, which was beyond the topic of the present study.

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TREND ODNOSA MORFOLOŠKIH KARAKTERISTIKA I MOTORIČKIH SPOSOBNOSTI PREDŠKOLSKE DJECE

S A Ž E T A K

Na velikom uzorku od 1170 djece, 565 dječaka i 605 djevojčica, u dobi od 4 do 7.5 decimalnih godina, iz predškolskih ustanova iz tri vojvođanska grada (Novi Sad, Sombor i Bačka Palanka) izmjereno je osam antropometrijskih karakteristika i primijenjena baterija od sedam motoričkih testova. Djeca su bila izabrana prema dobi od pola decimalne godine u navedenom dobnom rasponu. Analizirana su stanja dječaka i djevojčica prema sedam dobnih kategorija, razlike prema dobi između dječaka i djevojčica, te odnosi između antropometrijskih karakteristika i motoričkih sposobnosti putem matrica interkorelacija i kanoničkom korelacijskom analizom. Utvrđene su općenito značajne razlike u antropometrijskim karakteristikama koje se odnose na rast kostiju u dužinu u korist dječaka, a onih koje se odnose na voluminoznost i potkožnu mast u korist djevojčica. U prostoru motoričkih varijabli značajne su razlike u funkcioniranju mehanizma za strukturiranje kretanja, mehanizma za sinergijsku regulaciju i mehanizma za regulaciju trajanja ekscitacije i to u korist dječaka, a u funkcioniranju mehanizma za regulaciju tonusa u korist djevojčica. Te razlike su generirale morfološke i motoričke strukture dječaka i djevojčica prema analiziranim dobnim skupinama odnosi kojih su pokazali različitu razinu statističke značajnosti. U najmlađoj i najstarijoj dobnoj skupini zapaža se generalnost strukture kanoničkih faktora i najveća značajnost u sudjelovanju u zajedničkoj varijanci ta dva prostora primijenjenih varijabli. Između tih dobnih skupina, odnosno između 4 i 7 godina, odnos između morfoloških karakteristika i motoričkih sposobnosti djece opada i lagano raste, što se pratilo koeficijentom determinacije između prvih parova kanoničkih faktora u svakoj dobnoj kategoriji kako kod dječaka, tako i kod djevojčica. Uočeno je da je taj odnos viši kod dječaka kod svih analiziranih dobnih kategorija, osim u najmlađoj dobnoj skupini gdje je kod djevojčica zabilježena znatno viša razina povezanosti morfološke i motoričke strukture. Takav rezultat istraživanja tumači se trendom i razinom rasta i razvoja morfološke i razvojem motoričke strukture, razvojem središnjeg živčanog sustava, ali i tjelesnom aktivnošću koja je više izražena kod dječaka nego kod djevojčica.