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RELATIONSHIP BETWEEN MORPHOLOGICAL CHARACTERISTICS AND MOTOR ABILITIES OF BOYS AND GIRLS AGED FROM 11-14 IN THE PROVINCE OF VOJVODINA

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Abstract

The aim of this study was to examine the relationship between morphological characteristics and motor abilities of boys and girls aged from 11 to 14 so that the process of physical education could be in line with the dynamics of growth and development as well as the differences between the sexes. The total sample consisted of 730 subjects, divided into four age groups of 11, 12, 13 and 14. Eight motor tests were conducted and 9 anthropometric measures were taken. The boys of all ages achieved better results in tests of coordination, repetitive and explosive power, while girls of all age groups scored better in flexibility tests. The largest differences between the sexes at the ages of 11 and 12 years were the results of variables evaluating motor abilities. At the age of 13, a significant difference in skinfold thickness was found in favor of girls and at the age of 14 in the voluminousness in favor of boys. In boys aged from 13 and 14, the increase in body volume was negatively correlated with the increase in skinfold thickness, indicating that the increase of voluminousness is caused by the increase of muscle mass. It is therefore concluded that the linear increase of the differences in motor performance tests under 14 years of age is caused by increased muscle mass in boys, especially in tests where achievement depends on the strength and production of force.

Keywords: morphological characteristics, motor abilities, early adolescence

Introduction

The pattern of growth and maturation of children is generally similar in all children, but the size reached in a given year and the time of the sudden increase in growth and development of adolescents vary in each individual. Both sexes follow the same course of

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growth and development. The results showed that there is a wide range of specific features in the development of anthropometric characteristics and motor abilities in terms of heterochrony, and it is necessary to adjust physical education to the dynamics of growth and development, on the one hand, and differences in sexes on the other hand (Krsmanović, Batez, & Krsmanović, 2011). The phase of rapid development starts between the age of 11 and 14, and the height and weight increase faster. The rapid development occurs approximately 2 years earlier in girls than in boys (Beunen & Malina, 1988). The period of adolescence, i.e. accelerated development of boys, contributes to increased muscle mass and therefore to greater differences between the sexes (Dickerson & Widdiwson, 1960). In girls, the subcutaneous adipose tissue rapidly increases after the age of 8. During late adolescence, the amount of subcutaneous fat tissue in girls is twice as high as in boys (Malina & Johnson, 1967). There are larger differences between boys and girls during adolescence in skinfold thickness of the limbs than in skinfold thickness of the trunk. The boys become taller and heavier at the end of puberty and have more muscles and less fat (Burmeister, 1965), larger arm and chest circumferences, greater shoulder breadth, narrow hips and lower upper arm skinfold thickness during adolescence (Roche & Malina, 1983). Some researches indicate that the development of muscle tissue of upper extremities during adolescence is twice as high in boys as in girls (Eckert, 1974). Gender differences of young adolescents are greater in development of the musculature of the upper extremity than in development of the muscles of lower limbs (Dickerson & Widdiwson, 1960).

Specific features of growth, development and maturation of each child have influence on the development of motor skills. The environment in which the child grows also represents an important factor of motor development and the biological foundation of growth and maturation affecting the child's motor intelligence (Beunen & Malina, 1988). In boys linear progression of power goes through a period of childhood and adolescence until the age of 13-14, when this ability develops rapidly (Carron & Bailey, 1974). In girls a linear increase in power occurs over a period of childhood and adolescence until the age of 16-17 with no clear evidence of rapid progress as in boys (Thomas & French, 1985). The aim of this study was to determine the differences in morphological characteristics and motor abilities of boys and girls during the phase of early adolescence, analyzing the structure of differences for each age from 11 to 14 with the purpose of harmonizing physical education with the dynamics of growth and development and the differences between the sexes.

Method

The study was conducted on a sample of 730 subjects, 398 boys and 332 girls, aged from 11 to 14 years, mentally and physically healthy students of primary schools in the cities of Novi Sad, Sombor and Zrenjanin. The subjects were classified into four groups. The first group consisted of 165 subjects (93 boys and 72 girls aged 11 years), the second group of 224 subjects (117 boys and 107 girls aged 12 years), the third group of 202 subjects (112 boys and 90 girls aged 13 years), and the fourth group of 139 subjects (76 boys and 63 girls aged 14 years).

The following anthropometric variables were tested and measured according to the International Biological Protocol (IBP): height, weight, chest circumference, upper arm, forearm volume, abdominal volume, abdominal skinfold thickness, back skinfold thickness, upper arm skinfold thickness. The variables for motor abilities were obtained by applying the standardized motor tests (Bala, Stojanović, & Stojanović, 2007): obstacle course backwards and slalom with three balls for functional coordination, hand tapping to estimate the speed of the hands, sit-and-reach in straddle position to assess flexibility, standing broad jump and 20-

meter dash for assessment of explosive strength, bent-arm hang for assessment of static strength of the arm and shoulder muscles, sit-ups with arms crossed for assessment of repetitive trunk muscle strength.

The differences between the sexes in relation to motor abilities and morphological characteristics of each group were calculated by applying multivariate (MANOVA) and univariate (ANOVA) analysis of variance with adjustment of significance level of $p \leq 0.5$. The structure of differences in the total system of variables and the significance of each variable for discrimination between the sexes for each age group was analyzed by using the Canonical Discriminant Analysis. All statistical analyzes were performed by applying statistical program SPSS 15.0.

Results

Multivariate analysis of variance (MANOVA) showed statistically significant differences in anthropometric characteristics and motor abilities of boys and girls aged from 11 to 14 (Tables 1, 2, 3, 4, p = 0.00). The next step was determination of individual differences in each variable separately (ANOVA), analysis of variables contributing most to the discrimination of the subjects and analysis of directions of the differences within the applied system of variables (DISCRA). The largest contribution to gender discrimination was provided by the variable for evaluation of motor skills (explosive strength, coordination, and flexibility). In age groups of 11, 12 and 13 no significant differences in height of boys and girls were found ($p = 0.80$, $p = 0.13$, $p = 0.12$). Significant differences in height were found at the age of 14 ($p = 0.00$) in favor of boys (Table 5). Significant differences in body weight occur at the age of 12 and 14 ($p = 0.01$, $p = 0.00$) - boys had significantly higher body weight determined on the basis of group centroids (Table 5), while in age groups of 11 and 13 no significant differences were found. Between the age of 12 and 14, boys had a higher body volume. In relation to the volume, significant difference was observed only in abdominal girth ($p = 0.01$) in favor of boys at the age of 11 and no difference in voluminousness was found at the age of 13. Significant differences between the sexes in the amount of subcutaneous adipose tissue were observed at the age of 11 ($p = 0.93$, $p = 0.73$, $p = 0.90$) and 12 ($p = 0.60$, $p = 0.59$, $p = 0.13$). Significant differentiation in thickness of subcutaneous skinfold between the sexes was found at the age 13 ($p = 0.03$, $p = 0.02$, $p = 0.00$) and it increased linearly until the age of 14 ($p = 0.00$, $p = 0.03$, $p = 0.00$). Based on the position of group centroids (Table 5) during the period from 13 to 14 years of age, girls had more body fat than boys. The variable which contributed most was skinfold thickness of the forearm (Table 5).

Table 1

Descriptive statistics of boys and girls aged 11

Variable	Boys aged 11 (*N* = 93)		Girls aged 11 (*N* = 72)		*f*	*p*
	M	*SD*	*M*	*SD*		
Body height (mm)	1516.27	75.89	1513.36	69.98	0.64	0.80
Body weight(0,1kg)	431.17	99.02	415.00	81.87	1.25	0.24
Chest girth (mm)	717.34	72.34	693.50	92.67	3.44	0.06
Midarm girth (mm)	215.17	31.14	209.38	35.50	1.24	0.26
Forearm girth (mm)	201.88	21.31	194.72	27.83	3.50	0.06
Abdominal girth (mm)	670.81	91.74	638.74	78.92	5.52	**0.01**
Abdominal skinfold (0.1 mm)	148.58	99.63	149.86	82.19	0.88	0.93
Subscapular skinfold (0.1 mm)	96.19	65.25	99.53	58.35	0.16	0.73
Triceps skinfold (0.1 mm)	131.61	67.06	130.42	56.37	0.01	0.90
Obstacle course backwards(0.1 s)	163.73	46.33	191.18	51.84	12.83	**0.00**
Slalom with 3 balls (0.1 s)	365.41	70.16	413.32	62.29	20.09	**0.00**
Arm plate tapping (freq.)	27.10	4.26	27.78	3.52	1.22	0.27
Sit-and-reach (cm)	41.99	7.97	52.22	9.02	59.56	**0.00**
Standing broad jump (cm)	166.89	22.09	159.04	17.72	6.05	**0.01**
20-m dash (0.1 s)	43.05	3.86	44.21	3.63	3.81	**0.05**
Bent-arm hang (0.1 s)	313.37	233.69	243.74	190.84	4.21	**0.04**
Crossed-arm sit-ups (freq.)	37.16	8.37	34.11	7.12	6.12	**0.01**
			F=11.64	*p* =**0.00**		

N - number of participants; *M* - arithmetic mean; *SD* – standard deviation; *p* - level of significance

Table 2

Descriptive statistics of boys and girls aged 12

Variable	Boys aged 12 (*N* = 117)		Girls aged 12 (*N* = 107)		*f*	*p*
	M	*SD*	*M*	*SD*		
Body height (mm)	1581.43	80.91	1566.36	68.49	2.24	0.13
Body weight(0,1kg)	502.49	117.37	465.93	111.80	5.66	**0.01**
Chest girth (mm)	751.08	91.57	726.50	85.23	4.30	**0.03**
Midarm girth (mm)	227.93	34.38	217.37	31.03	5.70	**0.01**
Forearm girth (mm)	213.95	22.93	203.19	20.63	13.53	**0.00**
Abdominal girth (mm)	712.93	104.03	672.29	92.69	9.46	**0.00**
Abdominal skinfold (0.1 mm)	161.64	95.43	155.61	78.27	0.26	0.60
Subscapular skinfold (0.1 mm)	98.50	63.97	102.90	58.25	0.28	0.59
Triceps skinfold (0.1 mm)	123.19	57.09	135.16	60.68	2.31	0.13
Obstacle course backwards(0.1 s)	157.36	47.29	180.09	48.64	12.56	**0.00**
Slalom with 3 balls (0.1 s)	349.62	59.68	401.81	77.75	32.0	**0.00**
Arm plate tapping (freq.)	28.67	4.514	28.10	3.55	1.06	0.30
Sit-and-reach (cm)	43.11	8.45	53.86	11.37	65.37	**0.00**
Standing broad jump (cm)	175.15	23.074	166.38	20.86	8.84	**0.00**
20-m dash (0.1 s)	41.01	3.55	43.57	3.52	30.68	**0.00**
Bent-arm hang (0.1 s)	310.06	235.06	263.92	169.16	2.79	0.09
Crossed-arm sit-ups (freq.)	39.31	7.842	35.73	8.04	11.35	**0.01**
			F = 14.60	*p* = **0.00**		

M - arithmetic mean; *SD* – standard deviation; *p* - level of significance

Concerning motor skills, significant differences between the sexes were found in the tests of coordination - obstacle course backwards and slalom with three balls at the age of 11 (*F* = 12.83, *p* = 0.00, F = 20.09, *p* = 0.00), and 12 (*F* = 12.56, *p* = 0.00, *f* = 12.56, *p* = 0.00), 13 (15.45, *p* = 0.00, *p* = 35.17) and 14 (F = 23.58, *p* = 0.00, *f* = 27.67, *p* = 0.00) in favor of boys. Linear increase in the difference from 11 and 14 years was observed in obstacle course backwards, while in slalom with three balls the linear increase of the difference occurred between the ages of 11 and 13 and at the age of 14 the difference decreased.

Table 3

Descriptive statistics of boys and girls aged 13

Variable	Boys aged 13 (N = 112)		Girls aged 13 (N = 90)		f	p
	M	*SD*	*M*	*SD*		
Body height (mm)	1636.34	94.35	1617.10	71.37	2.42	0.12
Body weight(0,1kg)	525.21	100.84	516.98	95.84	0.37	0.55
Chest girth (mm)	770.59	67.63	755.97	82.77	1.90	0.16
Midarm girth (mm)	227.37	29.83	225.47	24.38	0.23	0.62
Forearm girth (mm)	214.89	20.58	140.88	92.59	0.06	0.93
Abdominal girth (mm)	710.98	84.80	690.78	80.13	2.96	0.08
Abdominal skinfold (0.1 mm)	140.88	92.51	165.29	69.47	4.30	**0.03**
Subscapular skinfold (0.1 mm)	95.38	66.25	115.08	54.59	5.14	**0.02**
Triceps skinfold (0.1 mm)	113.30	61.54	135.82	53.19	7.54	**0.00**
Obstacle course backwards(0.1 s)	146.21	47.55	171.33	41.95	15.45	**0.00**
Slalom with 3 balls (0.1 s)	319.16	52.55	373.63	80.18	33.17	**0.00**
Arm plate tapping (freq.)	30.79	4.12	30.18	4.33	1.03	0.31
Sit-and-reach (cm)	45.24	10.31	57.80	11.25	68.20	**0.00**
Standing broad jump (cm)	186.87	23.50	174.10	21.45	15.89	**0.00**
20-m dash (0.1 s)	40.33	3.26	42.72	3.41	25.71	**0.00**
Bent-arm hang (0.1 s)	369.44	223.05	270.98	173.17	11.81	**0.00**
Crossed-arm sit-ups (freq.)	42.05	6.87	39.03	7.99	8.13	**0.00**
			F = 13.57	p = **0.00**		

M - arithmetic mean; *SD* – standard deviation; *p* - level of significance

Based on the position of group centroids, boys achieved better results in tests of coordination in the period from 11 to 14 years of age (Table 5), while girls achieved significantly better results (p = 0.00) in the test of flexibility in sit-and-reach reach at the age from 11 to 14. In tests of explosive strength, long jump and running 20 meters, boys achieved significantly better results (Table 5) at all ages from 11 to 14 years in comparison to girls. No significant difference was found (p = 0.09) in bent-arm hang at the age of 12. The tests of static strength of arm and shoulder muscles and repetative strength in trunk muscles showed statistical significance at the ages of 11, 13 and 14 in favor of boys.

Table 4

Descriptive statistics of boys and girls aged 14

Variable	Boys aged 14 (*N* = 76)		Girls aged 14 (*N* = 63)		*f*	*p*
	M	*SD*	*M*	*SD*		
Body height (mm)	1731.29	87.06	1632.24	53.20	62.14	**0.00**
Body weight (0,1kg)	604.64	128.93	522.67	75.18	19.85	**0.00**
Chest girth (mm)	814.18	71.32	238.17	31.36	21.44	**0.00**
Midarm girth (mm)	238.17	31.36	224.84	21.82	8.23	**0.00**
Forearm girth (mm)	228.54	20.61	124.95	74.43	44.98	**0.00**
Abdominal girth (mm)	724.64	108.18	696.10	72.89	3.18	0.07
Abdominal skinfold (0.1 mm)	124.85	74.43	171.08	64.73	14.93	**0.00**
Subscapular skinfold (0.1 mm)	91.32	59.86	109.68	37.54	4.49	**0.03**
Triceps skinfold (0.1 mm)	100.32	53.49	135.14	37.47	18.93	**0.00**
Obstacle course backwards(0.1 s)	137.01	32.53	170.97	49.39	23.58	**0.00**
Slalom with 3 balls (0.1 s)	306.58	65.98	365.38	65.17	27.67	**0.00**
Arm plate tapping (freq.)	31.84	4.92	31.25	4.36	0.54	0.46
Sit-and-reach (cm)	49.57	8.82	61.00	10.85	46.95	**0.00**
Standing broad jump (cm)	206.04	24.52	178.00	22.90	47.78	**0.00**
20-m dash (0.1 s)	38.05	3.28	41.78	3.85	38.64	**0.00**
Bent-arm hang (0.1 s)	513.34	235.35	270.16	161.87	48.93	**0.00**
Crossed-arm sit-ups (freq.)	44.70	6.33	39.10	7.61	22.41	**0.00**
			F = 18.04	*p* = **0.00**		

M - arithmetic mean; *SD* – standard deviation; *p* - level of significance

Based on the position of group centroids (Table 5), boys had better results in tests of explosive strength and coordination while girls scored better in tests of flexibility. At the age of 14, the variables for evaluation of anthropometric characteristics are important contributors to gender discrimination. Based on the centroid position of the group, boys had greater height, weight and volume, whereas girls had higher values of body fat.

Table 5

Summary of canonical discriminant functions

Variable	Discriminant Function Structure			
	Age 11	Age 12	Age 13	Age 14
Body height (mm)	-0.17	-0.09	-0.09	-0.42
Body weight(0,1kg)	-0.07	-0.14	-0.03	-0.23
Chest girth (mm)	-0.12	-0.12	-0.08	-0.24
Midarm girth (mm)	-0.07	-0.14	-0.03	-0.15
Forearm girth (mm)	-0.12	-0.25	-0.01	-0.36
Abdominal girth (mm)	-0.16	-0.18	-0.10	-0.09
Abdominal skinfold (0.1 mm)	0.06	-0.03	0.13	0.20
Subscapular skinfold (0.1 mm)	0.23	0.03	0.14	0.14
Triceps skinfold (0.1 mm)	-0.08	-0.09	0.17	0.23
Obstacle course backwards(0.1 s)	0.24	0.21	0.24	0.26
Slalom with 3 balls (0.1 s)	0.30	0.34	0.36	0.28
Arm plate tapping (freq.)	0.07	-0.06	-0.06	-0.04
Sit-and-reach (cm)	0.52	0.49	0.51	0.36
Standing broad jump (cm)	-0.26	-0.18	-0.25	-0.37
20-m dash (0.1 s)	0.13	0.33	0.31	0.33
Bent-arm hang (0.1 s)	-0.13	-0.12	-0.21	-0.37
Crossed-arm sit-ups (freq.)	-0.16	-0.20	-0.18	-0.25
Canonical Correlation	0.75	0.73	0.74	0.84
Wilks Lambda	0.42	0.45	0.44	0.28
	131.78	168.81	157.07	162.24
p	0.00	0.00	0.00	0.00
Group		Group Centroids		
Boys	-1.01	-1.04	-1.00	-1.43
Girls	1.31	1.14	1.25	1.73

Discussion

Some studies have shown that during the early phase of growth, girls at one time have a higher body weight and height as a result of the fact that the period of rapid development occurs earlier in girls than in boys (Roche & Malina, 1983). This was not observed in this study and the obtained results show that between the ages of 11 and 13 boys and girls do not

differ significantly in height, weight and body volume. Differentiation between the sexes in the adipose tissue appears only at the year of 13. Subcutaneous adipose tissue in boys increases during the ages from 7 to 12, and decreases at the onset of puberty (Huang, Johnson, Flugeroa-Colon, Dwyer, & Goran, 2001), which was also evidenced by this study. In girls aged 13 and 14, the differences increase linearly and confirm the results of the research (Malina & Johnson, 1967) where the accumulation level of subcutaneous adipose tissue in girls is almost twice as high as in boys during the period of adolescence. Larger differences were observed in the upper arm skinfold thickness comparing to the abdomen and the back at age of 13 and 14 in favor of girls. This difference can be explained by a higher activity of lipoprotein lipase (LPL) enzyme complex in the extremities of girls, so mobilization of fat decreased as the result of the hormonal activity (Arner, Lithell, Wahrenberg, & Brönnegard, 1991). During the phase of adolescence boys are characterized by a reduction of subcutaneous adipose tissue of upper extremities, causing a relatively greater amount of subcutaneous fat accumulation in the trunk area at the age of 12, where the increased thickness of subcutaneous adipose tissue was found. Strength increases linearly over the period of childhood and adolescence until the age of 13, when it develops rapidly in boys (Carron & Bailey, 1974).

The differences in performance in the tests evaluating strength in this study increased from the age of 11 to 14, when the differences reached the maximum. It is assumed that the magnitude of differentiation between the sexes in the tests of the strength results from increased activity of anabolic hormones (testosterone), contributing to the increase of muscle mass, which directly correlates with the increased strength. Greater differences between the sexes in the voluminousness are parallel to the difference in the results in the tests of explosive strength, so it can be concluded that increased muscle mass increases explosive power.

In terms of performance tests, which include coordination of complex sequence of activities, the boys in early adolescence showed superiority over the girls. Selection and processing of the corresponding motor program is done on the basis of previously acquired skills, i.e. motor experience (Foran, 2001), developed more in boys than in girls through physical education and free time activities. Therefore, the differences in tests of coordination were expected. Boys achieved better results in the tests of repetitive trunk strength and static strength of arms and shoulders in the period from 11 to 14 years. The reason for such results can be attributed to the fact that during the period of adolescence, boys engage in more competitive games than girls, and participate in games which are characterized by long duration (Lever, 1976). Previous studies (Beunen & Malina, 1988, Brandt, Haubenstricker, & Seefeldt, 1984) have shown that girls in all periods of growth and development have a greater flexibility than boys, which was confirmed by this study as well. Boys had lower results in tests of flexibility in the period from 11 to 14 years, and the most prominent differences were observed in age groups of 12 and 13 years. These differences can be attributed to rapid growth in length of the lower extremities in boys, and increase in trunk length in girls during this period (Gasser, Muller, Kohler, & Prader, 1985). Linear increase of the differences in performance of motor tests over the period from 11 to 14 years is triggered by puberty in boys and by increased development of muscle mass and strength (Malina, 1995).

Biological and social environmental factors can be considered as causes of differences in motor skills (Thomas & French, 1985). Although the pressure of the environment can be extremely high during the adolescence (Thomas & French, 1985), this study has shown that biological factors play a major role in the differences in motor functioning in boys and girls aged 11 to 14, especially when achievement depends on strength and force production.

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