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Gender Differentiations of Cognitive-Motor Functioning in Prepubertal and Pubertal Children

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A B S T R A C T

The aim of this study was to determine cognitive and motor status factors in female and male children aged 10–14, as well as developmental and/or integration functions according to gender. The study included 162 girls and 134 boys aged 10–14, divided into four groups: 84 girls aged 10–12 (mean age 11.26, SD 0.68), 84 boys aged 10–12 (mean age 11.41, SD 0.50), 78 girls aged 13–14 (mean age 13.52, SD 0.63) and 50 boys aged 13–14 (mean age 13.21, SD 0.53). The significance of quantitative differences between boys and girls in the overall system of variables was defined based on the results of canonic discriminant analysis of variance, and within each variable based on the results on univariate analysis of variance (ANOVA). In the younger age group (10–12 years), girls were superior to boys in a test assessing flexibility (Seated straddle stretch), whereas, compared to girls, boys had greater strength of the trunk (Crossed-arm sit-ups), greater explosive strength of jump and sprint type (Standing broad jump and 20 m dash), and coordination (Obstacle course backwards and Steps laterally). In the older age group (13–14 years) differences in flexibility were even more prominent in favor of girls, whereas the differences in explosive strength increased in favor of boys, especially of the throwing type with better agility (Steps laterally), balance (Board balance) and greater static strength of arms and shoulders (Bent-arm hang). In order to determine qualitative differences between pubertal and prepubertal girls and boys, the matrix of variable inter-correlations was factorized by the procedure of principal components procedure, that were then transformed to promax solution. The results showed that cognitive functioning had a significant role in the motor efficacy of girls and boys aged 10 to 14. In the age group of 10–12 years, in females, cognitive functioning is related to the motor system which integrates the regulation of muscle tone with agility/coordination, whereas in males there is a relation between cognitive abilities and the regulator of speed of upper extremities movement frequency. In the age group of 13–14 years, in females, cognitive functioning is involved in forming the factors for regulation of coordination and the intensity of energy mobilization in lower extremities, and to some degree, in the factor for regulation of intensity of energy mobilization in upper extremities and strength of the trunk, whereas in males the integration of synergetic regulation of movement in terms of balance and agility in terms of speed of direction change is carried out with significant involvement of cognitive abilities.

Key words: *schoolgirls, schoolboys, age 10–14 years, cognitive-motor structures*

Introduction

Previous studies have generally confirmed the existence of significant positive correlations between motor and cognitive abilities, which increase with the motor task complexity and decrease with age[1,2]. Studies including adolescents, and more rarely small children, pointed to the relationship of complex motor tasks and intelligence. However, there are reports on the correlation of intelligence and speed of simple movements, equilibrium, agility and explosive strength[2,3].Studies have established the existence of positive correlation between intelligence and performance of complex motor tasks, and by analogy with specific motor skills in various sports. This relationship is explained by the speed of general information processing in the central nervous system and involvement of cognitive processes in motor activity. Cognitive processes and cognitive functioning are

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the central mechanisms of cortical regulation. Central nervous system has primarily integrative function and enables purposeful and adjustable behavior in humans. Integration at the cortical level is of utmost importance because purposeful behavior is directly related to the integrative function of the cerebral cortex. Integration also exists at the subcortical level, especially in the situations that require automated reactions. Luria (1973)[4] has demonstrated that tertiary zones of the cerebral cortex play a major role in providing simultaneous (spatial) syntheses and involve cortical areas of the visual, auditory, vestibular and tactile-kinesthetic analyzer.

In a sample of high-school students, Katić (1977)[5] found a high positive correlation of the coordination, speed and explosive strength test performance with the results achieved in the tests of visual spatialization (simultaneous processor) and perceptive reasoning (perceptive processor). Investigating relationships of motor abilities and knowledge of school subjects in high-school students, Katić (1988)[6] found that success in physical education depended significantly on the function of the simultaneous (parallel) and perceptive as well as serial processor in both male and female students.

Results in the study conducted by Bala and Katić (2009)[7] showed that in seven-year-old girls, as opposed to seven-year-old boys, processes of integration of motor and cognitive abilities are conducted faster and more powerfully. Studies conducted with first-grade students of elementary school also showed that in females, as opposed to males, the process of integration of aerobic endurance[8] and coordination[9] into morphological-motor system occurs earlier, i.e., faster. Also, factors of general motor efficacy, which are defined, besides by coordination, by regulators of force and velocity[10,11], are formed earlier.

Each stimulus received probably undergoes a double process, successive and simultaneous, while the degree of inclusion of either depends on the nature of the stimulus and task requirements, as well as on the personality traits. Female sex is believed to be superior in verbal reasoning in comparison to numerical reasoning, which may favor higher activation of the successive process relative to simultaneous process in the nervous system. In addition, communication between the brain hemispheres plays an important role in stimulus performance.

There are various theories[12,13] on all elements that are necessary in the creation of a motor program. Task length and structure are the two main characteristics that influence the process of motor program designing. When a child is acquiring a motor program (motor knowledge or skill), he/she starts doing it at a cortical level; as the program is being increasingly mastered and acquired, it is gradually done at subcortical level.

When a complex motor task is learned after numerous repetitions, the involvement of cerebral cortex is minimal, the motor task becomes automatic and only the signal for initiation of movement comes from cerebral cortex. Therefore, performing a non-automatic motor activity, which to a great extent involves an increased cortex activity, also activates intellectual functions related to cortex activity. This further means that the involvement of cortex functioning can be presented in three levels[14]:

1. Minimal cortex activity – during simple movements.
2. Partial cortex activity – during complex movements.
3. Dominant cortex activity – during cognitive tasks.

Complex motor tasks during the learning phase include cognitive processes, mainly perceptive, which is not the case with simple motor tasks. It can be said that the proper cognitive functioning depends on the proper perceptive system functioning. Furthermore, the learning rate of complex motor tasks is greatly influenced by the transfer of motor experience, i.e., previous participation in motor activities. Therefore, cognitive functions depending on integration of mechanisms responsible for receiving, transferring and decoding information in the central nervous system are related to the movement regulation mechanisms. Due to the fact that many of the motor behaviors are complex and contain some degree of cognitive behavior, it is assumed that the same and/or similar mechanisms are responsible for human motor and intellectual behavior. The regulation at the cortical level is carried out mainly through the outer regulation loop, in which feedback holds special significance. Efficient functioning of the central processor allows decoding and integration of information which reaches the perceptive analysis system through various afferent channels, later to be sent to the central processor, which ensures the decisions making relevant to resolving motor problems.

When a motor situation is not a problem situation and when cognitive activity is not required, the connection between motor abilities and intelligence can be explained only by information flow speed, which is important for both activities. In motor tasks which present a problem, the information flow speed accounts only for one part of mutual variance, while the other part of mutual variance is explained by the involvement of cognitive activity in resolving the motor problem. Higher connections of complex motor tasks and cognitive variables indicate that, apart from elementary information flow speed (which depends on various mechanisms responsible for excitation of central nervous system), complex motor tasks include such information flow that involves cognitive processing (information flow which includes both motor and cognitive information).

The significance of general cognitive activity grows with the information complexity increase of the motor task. A coordinated action of all areas of the central nervous system that are responsible for cognitive functioning, and not only of some segments, is required for complex motor activity which requires a new, unfamiliar way of reacting. Therefore, motor activity is neither independent nor relatively dependent human activity; it is rather a reflection of the integrated activity of the whole central nervous system.

Raven's Standard Progressive Matrices (SPM)[15] offer a very useful test tool for assessment of cognitive status in children and adolescents (age ≥11 years), while Raven's Colored Progressive Matrices are used on assessment of cognitive status in preschool and young schoolchildren[16]. It is a nonverbal test intended for g-factor measurement according to classic Spearman's terminology[17,18]. The SPM test-retest reliability was found to be as high as 0.96[19].

Chabris et al. (2006)[20] report on male science students and those who like computer games to prefer spatial visualization (visuospatial intelligence), while female humanist students and artists prefer object visualization (verbal intelligence). The individuals with spatial style are superior in mental rotation and labyrinth tasks, while those with object style are superior in complex object recognition. Based on higher correlations, the authors conclude that spatial visualization must be a more unified and homogeneous ability.

Katić and Bala, 2012[21] conducted a study with the aim of identifying and defining factors responsible for cognitive and motor development of girls in the period between 10 and 14 years of age, as well as the factors responsible for integration processes of cognitive and motor status related to age. In relation to that study, this study will analyze quantitative and qualitative differences between the sexes in cognitive-motor functioning in prepubertal and pubertal period.

Materials and Methods

Study subjects

The sample was drawn from the population of female schoolchildren in the city of Split, Croatia. The study included a sample of 162 female schoolchildren aged 10–14 years, divided into two groups:

- 84 girls aged 10–12 (mean 11.26, SD 0.68) years, and
- 78 girls aged 13–14 (mean 13.52, SD 0.63) years.

The sample was drawn from the population of school boys in the city of Split (Croatia). The study included a sample of 134 schoolboys, age 10–14 years, consisting of the following two subgroups:

- 84 boys, aged 10–12 years (mean 11.41, SD 0.50);
- 50 boys, aged 13–14 years (mean 13.21, SD 0.53).

Instruments

A battery of 11 motor tests used in this study was selected on the basis of experience in adult subjects. These tests estimate the effectiveness of the following functional mechanisms: movement structuring, tone and synergetic regulation, regulation of excitation intensity, and regulation of excitation duration (Gredelj *et al.*, 1975)[22]:

- to estimate functional coordination of primary motor abilities:
  1) Steps laterally,
  2) Obstacle course backwards;
- to estimate balance:
  3) Board balance;
- to estimate flexibility:
  4) Seated straddle stretch;
- to estimate frequency of simple movements:
  5) Arm plate tapping,
  6) One foot tapping;
- to estimate explosive strength power:
  7) Standing broad jump,
  8) 20-m dash,
  9) Medicine ball throw from supine position;
- to estimate repetitive strength of the trunk:
  10) Crossed-arm sit-ups;
- to estimate static strength of arms:
  11) Bent-arm hang.

Raven's SPM test consisting of 5 sets (A, B, C, D and E) of 12 tasks each was employed for assessment of the study subjects' cognitive status. According to Van der Ven and Ellis (2000)[23], the A, C and D sets are one-dimensional, while the B and E sets are not. Lynn et al. (2004)[24] conclude that, although yielding three factors on the first order, SPM yield g-factor on the second order. According to the cybernetic models of intelligence, the component of planning, deciding and target management is one of the components of the central information processing[25,26].

Data analysis

Basic statistic was calculated for both groups of girls and both groups of boys in each variable (mean and standard deviation), and the significance of quantitative differences between boys and girls in the overall system of variables was defined based on the results of canonical discriminant analysis, and within each variable based on the results on univariate analysis of variance (ANOVA). Qualitative differences were analyzed based on the results of factor analysis by factoring matrices of variable inter-correlations, Hotelling's method of principal components and Guttman-Kaiser's criterion for determining the number of significant principal components, i.e., factors. The initial solution was transformed into oblique solution, which allows inter-correlations between the factors, using promax solution. Based on the structure of the obtained factors, quantitative differences between girls and boys of two age groups (10–12 and 13–14 years) were analyzed.

Results

Mean ($\overline{X}$) and standard deviation (SD) of all the variables for the female and male group of children aged 10–12 years are shown in Table 1, and for the female and male group of children aged 13–14 years in Table 2. The same tables contain results of canonic discriminant analysis (DF and CanR) which show that statistically significant difference between girls and boys was found in the overall system of variables both in the 10–12 age group and in the 13–14 age group.

Since statistically significant difference between girls and boys was found in the overall system of variables by using canonic discriminant analysis, univariate analysis of variance (F-test) was used to determine levels of significance for each variable. Results obtained from such analysis indicate that there are statistically significant differences between gender in 6 motor variables in the 10–12 age group (Table 1) and in 7 motor variables in the 13–14 age group (Table 2), whereas no significant differences were found between the sexes in the test assessing cognitive functioning.

Statistically significant difference between boys and girls in performing applied motor tests was found in both age categories. In the younger age group (10–12), significant difference was found only in flexibility (Seated straddle stretch), in favor of girls, while boys had greater basic strength of the trunk (Crossed-arm sit-ups), greater explosive strength of jump and sprint type (Standing broad jump and 20m dash), and coordination (Obstacle course backwards and Steps laterally).

In the older age group (13–14 years) the difference in flexibility has increased in favor of girls, however, the difference in explosive strength has also increased, especially of throwing type, in favor of boys. Boys were also superior, although to a lesser extent, in agility (Steps laterally), balance (Board balance) and in static strength of arms and shoulders (Bent-arm hang).

After determining the quantitative differences, it was necessary to determine the qualitative differences between girls and boys of different age, especially since it involves prepubertal and pubertal age. For that purpose, the matrix of variable inter-correlations was calculated, which was factorized by Hotelling's procedure of principal components (H), and significant principal components were defined based on the Guttman-Kaiser criterion.

Table 3 shows significant principal components (H) for girls and boys aged 10–12 years. In girls, the isolated four principal components accounted for 63.18% of the total variability of applied variables, whereas in boys the isolated three principal components accounted for 56.91% of total variability of applied variables. The most important, first principal component accounts for 30.70% of that variability in girls and 32.04% in boys, but its structure is not easily defined, which is also true for other components. This is the reason why principal components were transformed into a promax solution, so their isolated factors were interpreted based on their systems (Table 4).

In girls:

The following variables exerted highest projections upon the first promax factor (Pattern Matrix) (Table 4): Bent arm hang – assessing static strength of upper extremities and/or muscle endurance; Arm plate tapping –

TABLE 1
DESCRIPTIVE STATISTICS AND RESULTS OF CANONICAL DISCRIMINATION ANALYSIS BETWEEN GIRLS AND BOYS – 10–12 YEARS

Variable	Girls=84	Boys=84	DF	F^A	p^A
	$\bar{X}$±SD	$\bar{X}$±SD			
Steps laterally# (s)	11.19±1.02	10.86±1.08	0.23	4.22	0.04
Obstacle course backwards# (s)	14.57±3.39	13.27±3.33	0.28	6.18	0.01
Board balance (s)	7.21±5.02	7.87±5.81	–0.09	0.61	0.43
Seated straddle stretch (cm)	57.36±12.95	46.70±9.54	0.68	36.83	0.00
Arm plate tapping (freq.)	29.13±3.19	29.60±2.93	–0.11	1.01	0.31
One foot tapping (freq.)	19.01±1.78	18.86±2.86	0.04	0.15	0.69
Standing broad jump (cm)	157.92±19.83	166.41±21.69	–0.30	7.00	0.01
20 m dash# (s)	4.43±0.33	4.31±0.37	0.25	4.90	0.02
Medicine ball throw (m)	4.10±0.90	4.17±0.91	–0.06	0.23	0.62
Crossed-arm sit-ups (freq.)	21.11±4.05	23.05±3.77	–0.36	10.26	0.00
Bent-arm hang (s)	13.90±12.43	15.29±16.57	–0.07	0.37	0.54
Raven's progressive matrices	44.09±7.36	43.64±7.44	0.05	0.15	0.69
Centroids	0.68	–0.68			
CanR			0.57*		

#variable with opposite metric orientation, *p<0.01

DF – discriminant function, F^A – F-test for ANOVA, p^A – probability for ANOVA, CanR – coefficient of canonical discrimination

TABLE 2
DESCRIPTIVE STATISTICS AND RESULTS OF CANONICAL DISCRIMINATION ANALYSIS BETWEEN GIRLS AND BOYS – 13–14 YEARS

Variable	Girls=78	Boys=50	DF	F^A	p^A
	$\bar{X}$±SD	$\bar{X}$±SD			
Steps laterally# (s)	10.43±1.08	9.88±1.72	0.13	4.94	0.02
Obstacle course backwards# (s)	14.09±3.87	12.99±3.80	0.09	2.51	0.11
Board balance (s)	6.39±5.39	8.52±6.24	–0.12	4.19	0.04
Seated straddle stretch (cm)	68.28±12.50	47.16±8.64	0.65	109.08	0.00
Arm plate tapping (freq.)	31.21±3.61	29.84±5.48	0.10	2.94	0.08
One foot tapping (freq.)	20.00±2.37	21.02±6.15	–0.08	1.74	0.18
Standing broad jump (cm)	160.60±20.05	183.56±27.68	–0.34	29.53	0.00
20 m dash# (s)	4.39±0.58	4.07±0.42	0.20	11.12	0.00
Medicine ball put – lieing (m)	4.53±0.73	5.72±1.62	–0.35	31.80	0.00
Crossed-arm sit-ups (freq.)	22.84±3.57	23.99±4.67	–0.09	2.45	0.11
Bent-arm hang (s)	15.65±12.18	20.50±16.02	–0.12	3.75	0.05
Raven's progressive matrices	46.75±6.96	45.52±7.79	0.05	0.87	0.35
Centroids	1.13	–1.76			
CanR			0.82*		

#variable with opposite metric orientation, *p<0.01

DF – discriminant function, F^A – F-test for ANOVA, p^A – probability for ANOVA, CanR – coefficient of canonical discrimination

TABLE 3
PRINCIPAL COMPONENTS IN GIRLS AND BOYS AGED 10–12 YEARS

Variable	Girls				Boys		
	H1	H2	H3	H4	H1	H2	H3
Steps laterally	–0.72	0.07	–0.27	0.11	–0.69	–0.30	0.11
Obstacle course backwards	–0.79	0.13	0.19	–0.04	–0.82	0.16	–0.01
Board balance	0.07	0.77	0.17	–0.40	0.56	–0.33	0.28
Seated straddle stretch	0.31	–0.53	0.41	–0.06	0.07	0.62	–0.07
Arm plate tapping	0.49	0.29	–0.42	–0.05	0.31	0.40	0.62
One-foot tapping	0.27	0.52	0.34	0.10	0.55	–0.39	0.40
Standing broad jump	0.82	0.11	0.16	–0.17	0.71	0.37	–0.23
20-m dash	–0.79	0.13	0.19	–0.04	–0.68	0.38	0.15
Medicine ball throw	0.15	0.31	0.48	0.51	0.28	0.24	–0.47
Crossed-arm sit-ups	0.53	–0.16	–0.05	0.63	0.59	0.33	–0.16
Bent-arm hang	0.62	0.11	–0.47	0.07	0.73	–0.18	–0.05
Raven's Progressive Matrices	0.28	–0.49	0.20	–0.38	0.06	0.46	0.59
Eigen value	3.68	1.67	1.14	1.07	3.84	1.64	1.33
% of Variance	30.70	13.97	9.55	8.95	32.04	13.74	11.12
Total % of Variance				63.18			56.91

assessing the speed of frequency of hand movements; Obstacle course backwards – assessing whole body coordination; and 20-m dash and Standing broad jump – assessing explosive strength (sprint and jump type). This factor defines general motor efficiency of prepubertal female children, which is underlain by the complex integrating muscle endurance and speed of upper extremity movements, whole body coordination and explosive strength of lower extremities. The factor will be named: The mechanism for integration of force, speed and coordination in which the dominated role is given to the activity of upper extremities.

The second promax factor is predominantly defined by the following three variables: Seated straddle stretch – assessing muscle tone; Raven's Progressive Matrices – a test assessing general cognitive factor; and Steps laterally – assessing the factor of coordination/agility. The second promax factor is underlain by the integration of

TABLE 4
PATTERN MATRICES (A) IN GIRLS AND BOYS AGED 10–12 YEARS

Variable	Pattern Matrix (Girls)				Pattern Matrix (Boys)		
	A1	A2	A3	A4	A1	A2	A3
Steps laterally	–0.28	–0.52	–0.16	–0.08	–0.18	–0.65	–0.11
Obstacle course backwards	–0.75	–0.18	0.07	0.18	–0.67	–0.29	0.00
Board balance	0.06	–0.16	0.18	0.85	0.74	–0.13	0.11
Seated straddle stretch	–0.26	0.77	0.06	–0.22	–0.44	0.52	0.26
Arm plate tapping	0.83	–0.30	–0.16	0.12	0.16	0.05	0.77
One-foot tapping	–0.01	–0.08	0.59	0.37	0.83	–0.25	0.19
Standing broad jump	0.49	0.38	0.13	0.22	0.10	0.79	0.06
20-m dash	–0.62	–0.31	0.02	–0.08	–0.67	–0.18	0.27
Medicine ball throw	–0.28	–0.09	0.88	–0.02	–0.19	0.62	–0.25
Crossed-arm sit-ups	0.39	–0.08	0.42	–0.57	0.07	0.65	0.07
Bent-arm hang	0.94	–0.24	–0.17	–0.09	0.60	0.28	–0.07
Raven's Progressive Matrices	–0.06	0.76	–0.32	–0.03	–0.05	–0.01	0.76

muscle tone regulation and agility (predominantly occurring at subcortical level) with general cognitive ability.

The third promax factor is predominantly defined by the variable assessing explosive strength of throwing type (Medicine ball throw from supine position), which is significantly saturated by the abilities of the speed of lower extremity movements and repetitive strength of the trunk. The fourth promax factor is predominantly defined by the variable assessing equilibrium, which is underlain by the mechanism of synergistic regulation and to a certain extent counteracted by the development of repetitive strength of the trunk.

In boys:

The highest projections upon the first promax factor (Pattern Matrix) were exerted by these variables (Table 4): One-foot tapping – assessing the speed of frequency of foot movements, Board balance – assessing balance (synergetic regulation of movement), Obstacle course backwards – assessing whole body coordination, 20m dash – assessing explosive strength (sprint type) and Bent-arm hang – assessing static strength of upper extremities and/or muscle endurance. This factor defines general motor efficacy of prepubertal boys which is underlain with a system integrating the speed of movement of lower extremities, balance, whole body coordination, explosive strength of sprint type and muscle endurance. The factor will be named: The mechanism for integration of speed, force and coordination primarily of lower extremities.

The second promax factor is predominantly defined by these variables: Standing broad jump – assessing coordination/agility factors, Crossed-arm sit-ups – assessing basic strength of the trunk, Medicine ball throw from supine position – assessing explosive strength of throwing type and Seated straddle stretch – assessing muscle tone. The second promax factor is underlain with integration of explosive strength, basic strength of the trunk, coordination/agility and muscle tone (which mainly takes place at subcortical level). The factor will be named: The mechanism for regulation of energy mobilization intensity which is saturated with agility and muscle tone.

The third promax factor is predominantly defined with two variables, these being Arm plate tapping – assessing the speed of frequency of movement of upper extremities and Raven's progressive matrices – test assessing general cognitive factor. This factor is underlain with speed of information flow, i.e. serial information processing.

Table 5 shows significant principal components (H) for girls and boys aged 13–14. Four principal components isolated in girls accounted for 63.64% of total variability of applied variables. The first principal component accounts for 31.78% of that variability, and it shows that motor functioning of girls of this age is predominated by integration of coordination, psychomotor speed and explosive strength, which is related to cognitive ability. Four principal components isolated in boys accounted for 67.32% of total variability of applied variables. The first principal component accounts for 26.68% of that variability, and it shows that motor functioning of boys of this age is predominated by integration of all factors of strength and coordination. However, in order to make a more clear definition of the first as well as the other factors, principal components were transformed into a promax solution, and isolated factors were interpreted based on their systems (Table 6).

In girls:

The variables assessing explosive strength (sprint and jump type), the variables assessing the speed of frequency of lower extremity movements, the variable assessing agility/coordination and the variable assessing cognitive functioning elicited significant projections upon the first promax factor (Pattern Matrix) (Table 6). This factor defines general motor efficiency of pubertal girls, which is underlain by the complex integrating ex-

TABLE 5
PRINCIPAL COMPONENTS IN GIRLS AND BOYS AGED 13–14 YEARS

Variable	Girls				Boys			
	H1	H2	H3	H4	H1	H2	H3	H4
Steps laterally	–0.77	–0.05	0.13	0.02	–0.66	–0.21	0.15	0.34
Obstacle course backwards	–0.63	0.33	–0.44	–0.04	–0.59	0.37	–0.56	0.18
Board balance	0.30	0.62	–0.10	0.32	0.04	0.65	–0.04	–0.10
Seated straddle stretch	0.58	–0.07	0.67	0.12	–0.05	–0.61	–0.05	0.49
Arm plate tapping	0.62	0.31	0.11	–0.14	–0.26	0.22	0.80	0.29
One-foot tapping	0.71	–0.12	–0.08	–0.34	–0.21	0.65	–0.23	0.53
Standing broad jump	0.70	0.08	0.04	–0.40	0.77	–0.20	0.18	0.25
20-m dash	–0.47	–0.23	0.45	0.21	–0.73	–0.03	0.06	–0.23
Medicine ball throw	0.42	–0.05	–0.19	0.70	0.67	–0.13	–0.57	–0.02
Crossed-arm sit-ups	0.58	–0.34	–0.15	0.39	0.62	0.31	–0.02	0.47
Bent-arm hang	0.08	0.77	0.22	0.11	0.47	0.14	0.38	–0.07
Raven's Progressive Matrices	0.48	–0.19	–0.46	–0.01	0.25	0.67	0.18	–0.20
Eigen value	3.82	1.43	1.23	1.13	3.20	2.10	1.59	1.17
% of Variance	31.87	11.97	10.31	9.47	26.68	17.56	13.26	9.81
Total % of Variance				63.64				67.32

plosive strength of lower extremities, psychomotor speed, agility/coordination and general cognitive ability. The first factor is underlain with the coupling of subcortical movement regulation and cognitive functioning.

The second promax factor is predominantly defined by the following two variables: Seated straddle stretch (flexibility) and Obstacle course backwards (coordination), and is underlain by cortical regulation of muscle tone.

The third promax factor is predominantly defined by the variable assessing explosive strength of throwing type (Medicine ball throw from supine position) and the variable of repetitive strength of the trunk (Crossed-arm sit-ups), with integration of the explosive strength of upper extremities and basic strength of the trunk to achieve maximal force on throwing (medicine ball, ball, shot, javelin, etc.). This type of integration of motor abilities is cognitively saturated to some extent.

The fourth promax factor (Pattern Matrix) is predominantly defined by the variable assessing static strength of upper extremities and/or muscle strength (Bent-arm hang) and the variable assessing equilibrium (balance), which is underlain by the mechanism of synergistic regulation (Board balance). This implies integration of the mechanism responsible for muscle endurance and mechanism responsible for synergistic regulation of movements, aiming at optimal energy consumption on fixa-

TABLE 6
PATTERN MATRICES (A) IN GIRLS AND BOYS AGED 13–14 YEARS

Variable	Pattern Matrix Girls				Pattern Matrix Boys			
	A1	A2	A3	A4	A1	A2	A3	A4
Steps laterally	–0.59	–0.13	–0.21	–0.10	–0.22	–0.46	0.22	0.41
Obstacle course backwards	–0.07	–0.76	–0.15	0.17	–0.30	0.03	0.79	–0.20
Board balance	0.10	–0.11	0.27	0.70	0.01	0.58	0.28	0.01
Seated straddle stretch	–0.10	0.91	0.07	0.12	0.28	–0.82	0.04	0.04
Arm plate tapping	0.50	0.24	–0.08	0.32	0.12	0.04	–0.03	0.93
One-foot tapping	0.74	0.16	–0.07	–0.16	0.32	0.11	0.89	0.15
Standing broad jump	0.75	0.22	–0.23	0.02	0.77	–0.20	–0.25	0.00
20-m dash	–0.76	0.35	–0.01	–0.13	–0.74	0.04	0.00	0.17
Medicine ball throw	–0.16	0.08	0.86	0.19	0.42	–0.07	0.03	–0.72
Crossed-arm sit-ups	0.10	0.20	0.66	–0.15	0.88	0.01	0.32	0.02
Bent-arm hang	–0.03	0.06	–0.12	0.79	0.33	0.27	–0.32	0.20
Raven's Progressive Matrices	0.54	–0.22	0.31	–0.19	0.10	0.73	0.04	0.12

tion, i.e. maintaining the position of particular body parts (e.g., endurance in rhythmic gymnastics as well as in maintaining ideal position of body parts, i.e. angles between body parts in throwing events).

In boys:

Significant and predominant projections on the first promax factor (Pattern Matrix) are exerted by the variables assessing explosive strength (jump and sprint type), i.e. explosiveness of legs and the variable assessing repetitive strength of the trunk (Table 6). This factor defines motor efficacy of pubertal boys which is underlain with the integration of explosive strength of legs and basic strength of the trunk.

The second promax factor is predominantly defined by general cognitive ability which is positively followed by balance, that is synergistic movement regulation and coordination/agility, and negatively by flexibility, i.e. muscle tone regulation.

The third promax factor is predominantly defined by the variable assessing frequency of movement of lower extremities which is opposed by the development of the whole body coordination, while the fourth promax factor (Pattern Matrix) is predominantly defined by the variable assessing frequency of movement of upper extremities which is opposed by the development of explosive strength of throwing type.

Discussion

In accordance with the obtained results, quantitative gender differentiations of cognitive and motor abilities in prepuberty and puberty will be discussed first, which will be followed by the comparison of cognitive-motor structures according to gender and age, i.e. development phases.

In the younger age group (10–12 years) girls are superior to boys in flexibility (Seated straddle stretch), which is manifested in greater motion range of a certain joint or series of joints i.e. joint mobility, as well as in fluidness and gracefulness of movements. Flexibility is underlain with a mechanism regulating the muscle tone, which functions much better in females. The motor efficacy of boys as opposed to girls is reflected in greater strength of the trunk (Crossed-arm sit-ups), greater explosive strength of jump and sprint type (Standing broad jump and 20 m dash), and coordination (Obstacle course backwards and Steps laterally).

In the older age group (13–14 years) differences in flexibility are even more distinct in favor of girls, which facilitates movements of greater amplitude. However, the difference in explosive strength in favor of boys has increased, especially of the throwing type with greater agility (Steps laterally), balance (Board balance) and greater static strength of arms and shoulder belt (Bent-arm hang). Obviously, males have developed greater muscle mass as opposed to girls.

Gender differentiations are much more distinct in puberty than in prepuberty, which indicates that development trend of certain motor abilities differs according to gender with the exception of psychomotor speed development. It has also been established that there were no significant differences between the sexes and that the development trend of these abilities does not differ according to gender.

It must be noted that differences have been found[8], according to gender, in preschool and early school period, i.e. from 4 to 7 years of age[27] in the same motor abilities as in this study (from 10 to 14 years of age) in which these differences are much more prominent.

Cognitive-motor functioning differs according to gender and age. This is the reason to consider isolated factors which are greatly defined in parallel by cognitive and motor abilities. A mechanism regulating either speed of simple information flow (for example movement frequency) or speed of complex information flow (for example speed of direction change) in which at least two motor abilities are integrated is always responsible for the correlation of cognitive and motor abilities. Therefore, both motor and cognitive functioning depends on functions of perceptive, serial and parallel information processing.

Simple movements are carried out based on existing programs in subcortical motor structures. In their execution, a signal for initiation of movement comes from the brain cortex; however, basic structures responsible for execution of movements are situated at a lower level (motor subcortical centers). With simple, alternative movements, timely relaxation of antagonists is important (e.g. tapping), and cognitive information flow is minimal.

During the execution of a complex motor task a learning process is present which includes cortex activity. With the increase of complexity of the motor task learned, the mobilization of cognitive abilities is also increasing. During the process of learning the complex motor task, the activity of the cortex is necessary because, in order to learn and perform the task, it has to be understood first. When a motor task is learned, a feedback system, or the regulation process is involved. When a motor task becomes automatic, the regulation process ceases and only the control process persists. With simple movements, only the control process is involved, and with complex movements in an experimental situation, primarily the regulation process is present, which also involves cognitive functioning.

In the younger age group (10–12 years), in females, the integration of muscle tone and agility regulation is supported by cognitive functions of perceptive and simultaneous information processing, whereas in males, the regulation of speed of frequency of movements of upper extremities is conditioned by the speed of information flow, i.e. by the function of the serial processor.

Motor tests applied consisted of several movements so the motor abilities assessed by these tests are regulators of performance of these movements. In this way, cognitive functions in females are simultaneously involved in muscle tone regulation and agility regulation, and in males, there is a correlation of cognitive abilities and the regulator of speed of frequency of movements of upper extremities.

During the realization of a simple motor task, the speed by which information reaches the effectors from the kinetic centre, the speed by which it passes the synapses, and the speed required for the kinetic center to emit signals is very important. The speed needed for the signal to pass the synapse is of crucial importance for the speed of information flow, whether the information flow occurs on a motor or an intellectual basis. When a motor task is so simple that there is no learning process, the speed of information flow becomes an important factor which conditions the speed of task performance. The activity of the reticular formation or the reticular activation system (RAS) is of great importance for the speed of information flow. Greater excitation enables greater emission of motor messages to the effectors and faster synaptic transmission. The fact that intensive intellectual work is accompanied by increased muscle tension confirms the existence of general excitation mechanisms of the central nervous system. Given that RAS is the main mechanism responsible for excitation level of CNS, it can be assumed that activity of this system, as well as of those systems which are directly linked to it, is for the most part responsible for the correlation of intelligence and the speed of performance of simple movements. Therefore, the ability to generate excitation is the basis which enables fast information transfer.

The optimal size of CNS excitation (interaction of RAS and cortex activity) and maximum speed of synaptic transmission have a very important impact in the complex motor functioning, as well as in intellectual functioning. Action efficiency depends on the synchronized activity of these subsystems with other parts of CNS, which is based on fast and efficient information flow[14].

During the process of learning a motor task, the cortex has a dominant role. In such assignments which do not involve a completely new situation, especially with persons who participated or still participate in some kinesiological activity, important parts of the cortex are those which store long-term memory, that is those motor programs which haven't been used for some time, especially those parts of the motor cortex which store efficient programs (kinetic memory). This means that cognitive activity, besides forming a new program, also participates in reconstructing an existing one. At the beginning of the process of learning a motor task, the information component is much more important than the energetic component.

In the older age group (13–14 years), in females, two factors of cognitive motor functioning are formed, which are: the first one in which efficacy of motor functioning depends on the integration of explosive strength of the feet, psychomotor speed and agility, with significant involvement of cognitive abilities, and the second one in which the efficacy of motor functioning depends on integration of explosive strength of the throwing type and repetitive strength of the trunk, which is somewhat cognitively conditioned. It is obvious that greater development of coordination and psychomotor speed in older girls in comparison to younger girls contributes to manifestation of explosive strength of lower extremities, as well as the fact that all of this occurs with the parallel development of cognitive functions. Parallel regulation of repetitive strength of the trunk and explosive strength of upper extremities involves cognitive abilities.

In males (13–14 years), the integration of synergetic regulation of movement in terms of balance and speed of direction change in terms of agility is carried out with much participation of cognitive abilities. Intensive development of motor abilities of balance and agility is accompanied by the development of cognitive abilities, and the regulation of these motor as well as cognitive abilities affects the efficiency of boys of this age.

It has been established earlier[7] that the cognitive aspect of functioning correlates more with the motor functioning in girls than in boys. However, the correlation of cognitive and motor sphere is much more distinct in prepubertal and even more in pubertal children in this study. The cause of greater correlation of cognitive and motor functioning in females is linked to the faster and stronger development in puberty, during which, besides other anthropological features, some motor abilities have a different development pace, which overall affects greater cognitive activity in integration and regulation of motor functions in females in comparison to males.

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SPOLNE DIFERENCIJACIJE KOGNITIVNO-MOTORIČKOG FUNKCIONIRANJA DJECE U PREDPUBERTETU I PUBERTETU

S A Ž E T A K

Cilj ovog istraživanja je utvrditi faktore kognitivnog i motoričkog statusa kod djevojčica i dječaka u periodu od 10–14 godina, kao i razvojne i/ili integracijske funkcije u odnosu na spol. U istraživanju je uključeno 162 djevojčice i 134 dječaka u dobi od 10–14 godina, podijeljenih u četiri skupine: 84 djevojčice u dobi od 10–12 godina (srednja dob 11,26 godina, SD 0,68), 84 dječaka u dobi od 10–12 godina (srednja dob 11,41 godina, SD 0,50), 78 djevojčice u dobi od 13–14 godina (srednja dob 13,52 godina, SD 0,63) i 50 dječaka u dobi od 13–14 godina (srednja dob 13,21 godina, SD 0,53). Značajnost kvantitativnih razlika između dječaka i djevojčica u cjelokupnom prostoru varijabli definirana je na osnovu rezultata kanoničke diskriminativne analize, a u svakoj varijabli na osnovu rezultata univarijatne analize varijance (ANOVA). Kod mlađe uzrasne dobi (10–12 godina) djevojčice su superiornije od dječaka u fleksibilnosti (Seated straddle stretch), dok dječaci u odnosu na djevojčice imaju veću snagu trupa (Crossed-arm sit-ups), veću eksplozivnu snagu tipa skoka i sprinta (Standing broad jump and 20 m dash), te koordinaciju (Obstacle course backwards and Steps laterally). Kod starije uzrasne dobi (13–14 godina) razlike u fleksibilnosti su još izrazitije u korist djevojčica, dok su se povećale razlike u eksplozivnoj snazi u korist dječaka (Standing broad jump and 20 m dash), posebno tipa bacanja (Medicine ball put – lieing), uz bolju agilnost (Steps laterally), ravnotežu (Board balance) i veću statičku snagu ruku i ramenog pojasa (Bent-arm hang). Za utvrđivanje kvalitativnih razlika između djevojčica i dječaka u predpubertetu i pubertetu matrica interkorelacija varijabli je faktorizirana postupkom glavnih komponenti, koje su potom transformirane u promax soluciju. Rezultati su pokazali kako kognitivno funkcioniranje značajno sudjeluje u motoričkoj efikasnosti djevojčica i dječaka uzrasne dobi od 10 do 14 godina. U starosnoj dobi od 10–12 godina, kod ženskog spola kognitivno funkcioniranje je povezano sa motoričkim sklopom koji integrira regulaciju mišićnog tonusa i agilnost/koordinaciju dok je kod muškog spola povezanost kognitivnih sposobnosti s regulatorom brzine frekvencije pokreta gornjih ekstremiteta. U starosnoj dobi od 13–14 godina, kod ženskog spola kognitivno funkcioniranje sudjeluje u formiranju faktora za regulaciju koordinacije i intenziteta mobilizacije energije donjih ekstremiteta i donekle u faktoru za regulaciju intenziteta mobilizacije energije gornjih ekstremiteta i snage trupa, dok se kod muškog spola integracija sinergijske regulacije kretanja u vidu ravnoteže i agilnosti u vidu brzine promjene pravca kretanja odvija uz značajno sudjelovanje kognitivnih sposobnosti.