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Original Article

Factorial and discriminant analysis as methodological basis of pedagogic control over motor and functional fitness of 14–16 year old girls

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Abstract
The purpose of the research: to determine methodological approaches to pedagogic control over 14–16 years' age girls' motor and functional fitness. *Material and methods:* in the research girls of 14 years' age (n=31), 15 years' age (n= 26), 16 years' age (n= 28) participated. For determination of informative indicators of pedagogic control over girls' motor and functional fitness we carried out factorial and discriminant analysis. *Results:* It was noted, that it was necessary to conduct factorial and functional analysis of children's and adolescents' motor fitness. Factorial and discriminant model of dynamic of girls' motor and functional fitness id the basis for optimization of pedagogic control at physical culture lessons in schools. In factorial model of 14 years' age girls' motor and functional fitness the place of priority is taken by functional fitness of respiratory and cardio-vascular systems; coordination and power fitness; speed-power fitness. For 15 years' age girls' motor and functional fitness the place of priority is taken by functional fitness of respiratory and cardio-vascular systems; coordination and power fitness; differentiation of space motor characteristics. For 16 years' age girls' motor and functional fitness the place of priority is taken by functional fitness of respiratory and cardio-vascular systems; power fitness; power endurance. *Conclusions:* for final pedagogic control over 14–16 years' age girls' motor and functional fitness first discriminant function with accent on the most informative variables can be used.
Key words: pedagogic control; girls; functional fitness; coordination fitness; motor abilities.

Introduction

Reduction of schoolchildren's motor functioning, low their organism's resistance to morbidity force to solve problems on effectiveness of physical education system in schools (Krucevich, 2012; Tkachenko, 2014; Krucevich & Ishchenko, 2015). Results of researches show that motor functioning is one of the most powerful means for ensuring of general and targeted development of organism's functions and systems (Baltsevych, 2000; Ilyin, 2003; Krutsevych & Bezverkhnya, 2010; Krucevich & Pangelova, 2014). In conditions of radical restructuring of physical education in educational system one of factors of pupils' motor functioning's intensification is organization of pedagogic control at physical culture lessons (Khudolii, 2008; Samokish, 2010; Rafal, 2013; Khudolii & Ivashchenko, 2014) and in conditions of sports training (Artemenko, 2009; Khudolii & Iermakov, 2011; Liu, 2015; Ivashchenko et al., 2015a; Podrigalo, Iermakov, Galashko, Galashko, & Dzhym, 2015). Pedagogic control procedure implies classification of motor and functional fitness current state, which influence on taking of decisions in control over children's and adolescents' physical education. So classification of motor fitness is of practical importance for taking decisions in control over physical education and in working out effective programs of children's and adolescents' physical education.

In researches of different scientists (Lopat'yev, 2007; Iermakov, Adashevskiy, & Sivolap, 2010; Adashevskiy, Iermakov, & Firsova, 2013; Arefiev, 2014; Podrigalo, Iermakov, Nosko, Galashko, & Galashko, 2015) conceptual approaches to simulation of training process and development of motor abilities in physical education and sports were worked out. The authors regard models of motor abilities' training, which can be used for current and final control of children's and adolescents' fitness. By the data of different authors (Ivashchenko, Yermakova, Cieslicka, & Zukowska, 2015; Ivashchenko, Yermakova, Cieslicka, & Muszkieta, 2015; Khudolii, Iermakov, & Ananchenko, 2015; Khudolii, Iermakov, & Prusik, 2015) current control over children's and adolescents' motor fitness can be fulfilled on the base of multi-dimensional methods and models.

Numerous testing of 14–16 years' age girls permitted to determine specific features of fencing training ((Kabanova, 2007), race walking (Prusik, Prusik, Iermakov, & Kozina, 2012; Iermakov, Cieślicka, & Muszkieta, 2015; Tuisheva & Ivanenko, 2015), tennis (Jagiello & Jagiello, 2015), boxing (Aslaev & Kotova, 2015), swimming (Isaev, Erlikh, Nenasheva, Shepilov, & Romanova, 2014; Rovnaya,, Podrigalo, Iermakov, Prusik, &

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Cieślicka, 2014). Authors note that at all stages of training proper control with the help of tests is an integral part of junior sportsmen many years training. It permits to more effectively perfect components of junior sportsmen physical, technical and psychological training.

Physical exercises' practicing by 14–16 years' age girls requires consideration their physiological characteristics (Piatunina & Gajnanova, 2006; Leer & Zvereva, 2013; Kozina, Iermakov, Kuzmin, Kudryavtsev, & Galimov, 2016), hemo-dynamic types (Sokolov & Grechkina, 2008; Levushkin & Son'kin, 2009), environment (Prusik, Prusik, Kozina, & Iermakov, 2013; Mamaev & Ivanova, 2014).

In such cases it is necessary to base on objective metric information. Such information can be received in researches, which involve wide contingent of the tested. With it participants of experiment shall demonstrate stable concentration of attention and highly reliable results in series of repeated measurements (Zaporozhanov, 2013; Zaporozhanov, & Boraczynski, 2015; Zaporozhanov, Borachinski, & Nosko, 2015; Iermakov, Arziutov, & Jagiełło, 2016). In general, such approaches facilitate rising of effectiveness of pedagogic control over pupils' physical fitness. Application of well-substantiated methodic in school practice reduces influence of negative factors on adolescents' health.

In our previous researches we substantiated and improved system of pedagogic control over children's and adolescents' motor fitness. We stressed on possibility of classification of 14–16 years' age boys age distinctions on the base of functional and power fitness testing (Ivashchenko et al., 2015b). The offered by us methodic of summarizing motor and functional fitness control of 14–16 years' age schoolchildren (Ivashchenko et al., 2015a) and 17–18 years' age boys (Ivashchenko et al., 2015c) permitted to find the most informative variables, which influence on quality of learning. Alongside with it, classification of pupils by level of motor fitness according to their age permitted to confidently determine adequacy of the applied tests (Khudolii et al., 2015a, 2015b).

However, in available scientific literature insufficient attention is paid to application of simulation method for improvement of pedagogic control over motor and functional fitness of children and adolescents.

The purpose of the research is to determine methodological approaches to pedagogic control over 14–16 years' age girls' motor and functional fitness.

Material & methods

In the research girls of 14 years' age (n=31), 15 years' age (n= 26), 16 years' age (n= 28) participated.

Testing program included well-known tests: jumps with "additions" (quantity of jumps in pre-set corridor); shuttle run 4x9 m (sec.), Pressing ups in lying position (times), chin ups (times), hanging on bent arms (sec.), long jump from he spot (cm) (Khudolii & Ivashchenko, 2011; Khudolii, Ivashchenko, & Karpunets', 2012).

For assessment of functional state we used tests of Shtange, Genchy and Serkin (Dubrovskij, 2005).

Statistical analysis

Materials of the research were processed with program of statistical analysis – IBM SPSS 20. We fulfilled factorial and discriminant analysis. In factorial analysis we used model of principle components with rotation method: Varimax with Keiser's normalization. For every variable the following statistics were calculated: mean values, standard deviations, Student's t-criterion for independent samples.

In the process of discriminant analysis we created prognostic model for belonging to group. This model builds discriminant function (if there are more than two groups, the model builds a set of discriminant functions) in the form of linear combination of predictory variables. It ensures the best distribution of groups. These functions are built by a set of observations' results, for which their belonging to group is known. In the future, these functions can be used in new observations with known values of predictory variables and unknown group belonging.

For every variable the following statistics were calculated: mean values, standard deviations, univariate analysis of variance for every variable (Box's M test, intra-group correlation matrix, intra-group co-variance matrix, co-variance matrixes for separate groups, general co-variance matrix). For every canonic discriminant function we calculated the following: own value, percentage of variance, canonic correlation, Wilks' Lambda, Chi-square and for every step – apriory probabilities, coefficients of Fisher's function, non standartized conefficients of functions, Wilks' Lambda for every canonic function.

The research was conducted in compliance with WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects, 2013. The study protocol was approved by the Ethical Committee of H.S. Skovoroda Kharkiv National Pedagogical University.

Results

Analysis of testing results showed that positive statistically confident dynamic was observed in 14–15 years' age girls in tests: № 2 (Sutlle run 4x9 m, sec.), № 3 (Pressing ups in lying positions, times), № 4 (Chin ups, times), № 6 (Long jump from the spot, cm). Steady, statisically confident dynamic of testing results was pbserved in 14–16 years' age girls in functional tests. 16 years' age girls were assessed as health and trained. With age we observed statistically confident worsening of differentiation of motor space characteristics (test № 1 "Jumps with "additions", times").

For determination of functional and motor fitness structure of 14 years' age girls we conducted factorial analysis by 9 testing indicators. Results of analysis are given in table 1.

In the process of analysis we marked out four factors, which explain 72.364% of indicators' total variance (see table 1).

Table 1. Factorial model of motor and functional fitness of 14 years' age (n=31), 15 years' age (n=26) and 16 years' age (n=28) girls. Method of rotation is: Varimax with Keiser's normalization

№	Description of test	Age, years	Components				h^2
			1	2	3	4	
1	Jumps with additions, times	14	-.375		-.612	.358	.656
		15		.395	.876		.928
		16					.887
2	Shuttle run 4x9 m, sec.	14		.889			.833
		15	-.720		-.493		.905
		16					.798
3	Pressing ups in lying position, times	14		-.797		-.333	.762
		15	.900				.904
		16					.945
4	Chin ups, times	14	-.813		.306		.734
		15	.908				.862
		16					.910
5	Hanging on bent arms, sec.	14				.813	.691
		15	.911				.890
		16					.900
6	Long jump from the spot, cm.	14			.671		.522
		15	.909				.967
		16					.921
7	Shtange's test, sec.	14			.701		.647
		15		.405		.877	.964
		16					.959
8	Genchy's test, sec.	14	.799			.403	.814
		15		.942			.927
		16					.938
9	Serkin's test, sec.	14	.862			.326	.854
		15		.753	.404		.814
		16					.959
	Total explained variance, %	14	26.076	16.209	15.060	15.019	72.364
		15	42.745	21.521	15.336	11.076	90.678
		16	29.058	24.576	21.926	15.747	91.307

Factor 1 is the most informative (26.076%). This factor correlates with results of Genchy's and Serkin's functional tests and was named "functional fitness of respiratory and cardio-vascular systems".

Factor 2 (information value 16.209 %) correlates to the largest extent with indicators of coordination and power fitness: "Pressing ups in lying position (-.797) and "Shuttle run 4x9 m" (.889). The factor is bipolar: improvement of the mentioned indicators worsens this factor. It points at complex relations between development of strength and motor coordination in 14 years' age girls. The factor was named coordination and actually power fitness.

Factor 3 (information value 15.060%) correlates to the largest extent with indicators of speed-power fitness and differentiation of space motor characteristics: "Long jump from the spot" (.671) and "Jumps with additions" (-.612). Increase of jumps' results strengthens the factor. It was named speed-power fitness.

Factor 4 (information value 15.019%) correlates to the largest extent with indicators of static power fitness: "Hanging on bent arms" (.813). The factor was named "power endurance".

Thus, in factorial structure of 14 years' age girls' fitness the place of priority is taken by functional, coordination and power fitness.

Analysis of communities showed that the offered battery of tests is rather informative (see table 2). For 14 years' age girls the most informative indicators were: "Serkin's test" (0.854), "Shuttle run 4x9 m" (0.833), "Genchy's test" (.814), "Pressing ups in lying position" (.762).

For determination of functional and motor fitness structure of 15 years' age girls we conducted factorial analysis by 9 testing indicators. Results of analysis are given in tables 2, 3 and 4.

In the process of analysis we marked out four factors, which explain 90.678% of indicators' total variance (see table 2).

Factor 1 is the most informative (42.745%). This factor correlates with tests, characterizing actual power fitness, power endurance and speed-power fitness of 15 years' age girls. The factor was named coordination and power fitness.

Factor 2 (information value 21.521 %) correlates to the largest extent with indicators of functional fitness of respiratory and cardio-vascular systems: "Genchy's test (.942) and "Serkin's test" (.753). The factor was named functional readiness of respiratory and cardio-vascular systems.

Factor 3 (information value 15.336%) correlates to the largest extent with indicators of motor coordination "Jumps with additions" (.876). It was named "ability for differentiation of space motor characteristics". Factor 4 (information value 11.076%) correlates to the largest extent with indicators of "Shtange's test" (.877). This factor supplements the second factor.

Thus, in factorial structure of 15 years' age girls' fitness the place of priority is taken by functional, coordination and power fitness. Analysis of communities showed that the offered battery of tests is rather informative (see table 2). For 15 years' age girls the most informative indicators were: "Hanging on bent arms" (.967), "Jumps with additions" (.964), "Serkin's test" (0.928), "Shtange's test" (.927).

For determination of functional and motor fitness structure of 16 years' age girls we conducted factorial analysis by 9 testing indicators. Results of analysis are given in tables 1 – 4.

In the process of analysis we marked out four factors, which explain 91.307% of indicators' total variance (see table 2). Factor 1 is the most informative (29.058%). This factor correlates with functional tests (Genchy's and Serkin's). The factor was named functional fitness of respiratory and cardio-vascular systems.

Factor 2 (information value 24.576 %) correlates to the largest extent with indicators: "Pressing ups in lying position" (.952) and "Chin ups" (.850). The factor was named power fitness.

Factor 3 (information value 21.926%) correlates to the largest extent with indicators of static power and was named power endurance. Factor 4 (information value 15.747%) correlates to the largest extent with indicators "Shtange's test" (.948). This factor supplements the first factor.

Thus, in factorial structure of 16 years' age girls' fitness the place of priority is taken by functional, coordination and power fitness. Analysis of communities showed that the offered battery of tests is rather informative (see table 2–4). For 16 years' age girls the most informative indicators were: "Long jump from the spot" (.959), "Jumps with additions" (.959), "Genchy's test" (0.945), "Shtange's test" (.938).

To specify possibilities of motor and functional fitness assessment in 14–16 years' age girls we carried out discriminant analysis (see tables 2–4). The first canonic function explains results' variation by 86.8 %, the second – by 13.2 % that witness about their high information potential. Check up of functions points at statistical significance for all set even after deduction of the first function ($p < 0.001$; $\lambda_{12} = 0.029$; $\lambda_2 = 0.365$).

Table 2. Canonic discriminant function. Own values

Function	Own values	% of explained variance	Cumulative %	Canonic correlation
1	11.447	86.8	86.8	.959
2	1.736	13.2	100.0	.797

In table 3 we render normalized coefficients of canonic discriminant function, which permit to determine correlations of variables' contribution into function result. The highest contribution in function 1 is provided by variables of tests №2, №1 and №6: the higher are the values of these variables the higher is the value of function. The highest contribution in canonic function 2 is provided by variables of tests №5, №4 an 8: the higher are the values of these variables the higher is the value of function. First function explains results' variation by 86.8% ($p<0.001$), second – by 13.2% ($p<0.001$). The above said witnesses that it is possible to classify age distinctions of 14–16 years' age girls on the base of functional and motor fitness testing.

Table 3. Results of discriminant analysis of 14–16 years' age girls' functional and motor fitness

№ of test (variables)		Normalized coefficients Function		Structural coefficients Function		Coefficients of functions for classification of girls age		
	Description of test	1	2	1	2	14	15	16
1	Jumps with "additions", times	.420	.354	.306*	.001	9.618	5.922	6.249
2	Shuttle run 4×9 m, sec.	.697	.453	.514*	.334	60.009	51.143	51.224
3	Pressing ups in lying positions, times	.311	.557	-.177*	.071	2.945	2.452	2.638
4	Chin ups, times	.324	-1.046	.079	-.191*	-4.892	-4.591	-6.787
5	Hanging on bent arms, sec.	-.006	.988	-.125	.503*	-.121	-.367	-.019
6	Long jumps from the spot, cm.	-.837	.136	-.465*	.205	1.522	1.941	2.138
7	Shtange's test, sec.	-.342	-.116	-.310*	-.072	.626	.801	.826
8	Genchy's test, sec.	-.370	.658	-.265*	.115	.375	.442	.754
9	Serkin's test, sec.			-.214*	.086			
	(Constant)					-573.744	-516.379	-567.189

In table 3 structural coefficients of first canonic discriminant function are given, which are correlation coefficients of of variables and with function. For example, function is connected with variables to the largest extent in tests № 2, 6, 7 and 1; so substantial difference between girls of 14 and 15–16 years' age is obserevd in motor coordination, speed-power and results of Shtange's test. Structural coefficients of second canonic

discriminant function point at the fact that this function to the largest extent is connected with variables of tests № 5 and 4. So substantial difference between girls of 15 and 16 years' age is obserevd in static and relative strength of arms' muscles.

Table 4. Results of groups' classification

Results of groups' classification					*Functions in groups' centroids*		
	Classificator (age, years)	Predicted belonging to group (age, years)			Age, years	Function	
		14	15	16		1	2
Frequency	14	31	0	0	14	4.260	.406
	15	0	24	2			
Final data	16	0	1	27	15	-1.416	-1.870
	14	100.0	.0	0			
%	15	.0	92.3	7.7	16	-3.401	1.287
	16	.0	3.6	96.4			

In table 4 we give results of groups' classification: 96.5% of final grouped observations were classified correctly. Thus, canonic discriminant function can be used for classification of age peculiarities of 14–15 years' age girls' functional and motor fitness. In table 3 we also present centroids' coordinates for three groups. They permit to interpret canonic function in respect to its role in classification. On positive pole there is centroid for 14 years' age girls. On opposite pole there are centroids for 15 and 16 years' age girls. It witnesses about substantial difference in fitness of 14–16 years' age girls.

Graphic material (see fig.1) witnesses about density of objects inside every class and distinct border between classes. It permits to say that classification of 14–16 years' age girls is possible with the offered battery of tests. In table 2 we give coefficients of functions for classification of 14–16 years' age girls by level of their functional and motor fitness.

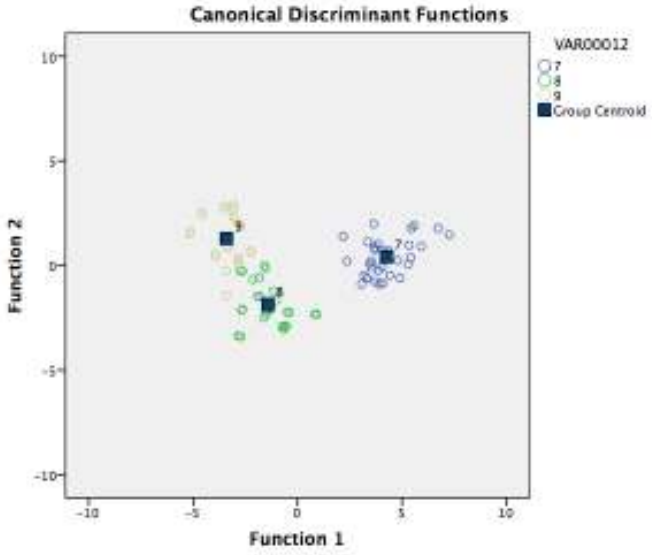

Fig. 1. Graphic picture of classification results

Discussion

The resecived results supplement the data about developm,ent of children'ss and adolescents' motor abilities (Marchenko, 2009; Iermakov, 2010; Khudolii & Titarenko, 2010; Khudolii, et al., 2012; Solianik, 2013), about simulation method's application for obtaining new information (Ivashchenko, 1988; Khudolii & Iermakov, 2011; Adashevskiy, Iermakov, & Marchenko, 2013; Ivashchenko et al., 2015b). In researches on physical education and sports discriminant function is used for classification of pupils by their motivation for sports practicing (Milić, Milavić, & Grgantov, 2014; Cieslicka, Napierala, Stankiewicz, & Iermakov, 2012), by motor functioning (Gert-Jan & Benjamin, 2011; Kozina & Iermakov, 2015), for classification of groups into sportsmen and not sportsmen (Bondarenko, 2011; Lulzim, 2012), for determination of children's physical condition dynamic under influence of special programs (Golenko, Mihuta, & Kuzmin, 2009; du Toit, Pienaar, & Truter, 2011), for final control of children's and adolescents' functional and motor fitness (Vertel & Gradusov, 2011; Ivashchenko et al., 2015c; Khudolii et al., 2015a, 2015b).

Discriminant analysis is a useful tool for determination of physical condition characteristic features (Lalanne, Falissard, Golse, & Vaivre-Douret, 2012). In discriminant analysis body mass index should be regarded as an important element for studying of physical condition's typology (Ko & You, 2015). With the help of discriminant analysis results of distinctions in children's physical fitness, conditioned by level of urbanization,

were received (Ujević, Sporis, Milanović, Pantelić, & Neljak, 2013). The purpose of next research was determination to what extent cognitive tasks on healthy life style and sports practicing facilitated increase of knowledge about cardio-respiratory component of trainings and health. Multi-dimensional discriminant analysis showed that cognitive tasks facilitated increment of knowledge (Zhang et al., 2014). Other authors used battery of 11 tests for motor abilities of 14–15 years' age pupils. They found that rising of motor abilities in that age could be optimally predicted by results of tests for quickness (Milojević & Stanković, 2010).

Application of discriminant analysis also permits the following: to determine changes in morphological characteristics and motor abilities of girls-sportswomen in comparison with their non sport peers (Shabatura, Tkachuk, Fed'ko, & Palinenko, 1987; Pryimakov, 1995; Lulzim, 2012); to distinguish 2 sub-groups of sportsmen-beginners: group with high rates of training and group with lower rates of success (Dercole, Dercole, Gobbi, & Gobbi, 2013). Other authors point at possibility to use discriminant analysis for classification of 5–12 years' age children's motor functioning, depending on its volume with equations of discriminant function. Such approach permits to classify correctly 93% of the grouped data (Broadhead & Church, 1982).

Application of discriminant analysis in our research permitted to find coefficients of discriminant function and, by their values, divide pupils into groups with maximal accuracy. Such approach permitted to solve two groups of problems:

- To answer the question how confidently it is possible to separate one class from the other by a set of the offered variables;
- Which of these variables influence to the largest extent on distinguishing of classes; to classify objects on the base of discriminant function (i.e. to answer: to what class object belongs on the base of discriminant variables' values).

Results of our research point that it is necessary to structurally and functionally analyze children's and adolescents' motor fitness. The carried out by us analysis proves that separation of 14 years' age girls from 15 and 16 eyars' age girls is possible with the set of the offered variables, accentuated on functional tests and results of speed-power fitness. So, discriminant analysis permitted to answer: how confidently it is possible to separate one class from he other by set of the offered variables; which of these variables influence to the largest extent on distinguishing of classes; to which class object belongs on the base of discriminant variables' values.

The received results supplement results of other authors:

- About demand in structural and functional analysis of children's and adolescents' motor fitness. Besides, these data prove the opinion that factorial model is a basis of pedagogic control over 14–16 years' age girls (Kravchuk & Kurochka, 2013; Ivashchenko et al., 2015c; Khudolii et al., 2015b)
- About high informative potential of Shtange's, Genchy's and Serkin's tests in assessment of pupils' functional state (Solianik, 2013; Veremeienko, 2013)
- About factorial structure of schoolchildren's motor fitness (Ivashchenko & Dudnik, 2011; Kozina & Popova, 2013).

The novelty of our research is that in factorial structure the place of priority is taken by functional, coordination and power fitness of 14–16 years' age girls.

Conclusions

Factorial and discriminant model of motor and functional fitness dynamic of 14, 15 and 16 years' age girls is the basis for optimization of pedagogic control at school physical culture lessons. In factorial model of 14 years' age girls' motor and functional fitness the place of priority is taken by functional fitness of respiratory and cardio-vascular systems; coordination and actually power fitness; by speed-power fitness. In factorial model of 15 years' age girls' motor and functional fitness the place of priority is taken by functional fitness of respiratory and cardio-vascular systems; coordination and power fitness. In factorial model of 16 years' age girls' motor and functional fitness the place of priority is taken by functional fitness of respiratory and cardio-vascular systems; power fitness and power endurance.

For pedagogic control of 14–16 years' age girls' motor and functional fitness the most informative are the following tests:

- For 14 years' age girls: "Serkin's test" (0.854), "Shuttle run 4x9 m" (0.833), "Genchy's test " (.814), "Pressing ups in lying position" (.762);
- For 15 years' age girls: "Hanging on bent arms" (.967), "Jumps with additions" (.964), "Serkin's test" (.928), "Shtange's test" (.927);
- For 16 years' age girls: "Jumps with additions" (.959), "Long jump from the spot" (.959), "Genchy's test" (.945), "Shtange's test" (.938).

Discriminant analysis permitted to solve two groups of problems:

- To answer how confidently it is possible to separate one class from he other by set of the offered variables;
- Which of these variables influence to the largest extent on distinguishing of classes;
- To classify objects on the base of discriminant function (i.e. to answer to which class object belongs on the base of discriminant variables' values).

Results of our research point that it is necessary to practice structural and functional analysis of children's and adolescents' motor fitness. For final pedagogic control of motor and functional fitness of 14–16 years' age girls first discriminant function with accent on the most informative variables can be used.

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