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Original Article

Enhancement of reserve capacities of the motion management system in female students with health deviations

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Abstract:
Purpose: The objective of the given study was to examine the reserve capacities of the systems of managing motions of different coordination structure in female students with health deviations and their enhancement by physical culture means. Material: The study involved 134 students of a special medical group (SMG) aged 17-19 with poor health. They were divided into two groups: control group (CG) and experimental group (EG). CG students participated in physical education (PE) classes in accordance with the state university program for SMG. In addition, a program aimed at increasing the reserves of the movement control system was implemented in EG. The basis of the program were physical exercises of complex coordination with innovative elements performed with musical accompaniment. The duration of the study was one academic year. Results: A positive influence of the experimental program on the manifestation of the motor function of students with poor health was demonstrated. The improvement of precise movements in EG was characterized by the increase of the quality of their regulation, the increase of the speed of the transition to the program mechanism for regulating movements in stable conditions of their performance, the increase of compensatory powers of transformations to maintain the stability of the motor function in complex conditions - with unfavorable factors and obstacles. This indicates the increase of the capacity of the reserve motion control system and is one of the criteria for these provisions. Conclusions: The main criteria for the reserve capacity of the motion control system with different coordination structures are: - speed of transition to the program control mechanism when controlling precise movements in stable operating conditions; - power and efficiency of compensation reactions, protecting the immunity of the motion control system when unfavorable factors occur; - stability of maintaining the quality of motion parameters in the optimum range when unfavorable factors occur; - reduction in the strength of interrelationships of sensory systems during motion control in stable conditions.
Key words: girl students, health, fine movements, reserve potentials, physical education.

Introduction

Motor function is one of the most ancient functions of living organisms (Bernshteyn, 1947). The problem of enhancing the reserves of motion management system in persons with health deviations should be referred to the least studied aspects of the problem of human motor system reserve capacity increase (Bernshteyn, 1947; Docenko, 2011; Pryimakov, Iermakov, Kolenkov, Samokish, & Juchno, 2017; Kobza, 1999).

System approach to revealing the problem of motor system functional capacities necessitates complex studies, aimed at examination of motion management mechanisms (Schnabel, 1994; Ghez,1985; Enoka, 1994), interactions of body systems in determination of different motions, their vegetative provision, health status of persons engaged in physical culture and sport, etc. (Mishchenko, 1990; Becker, 2015; Wilmore & Costill, 2005; Radzievskij, Pryimakov, Oleshko, & Iashchanin, 2002; Dolzhenko, 2004). Analysis of literary sources demonstrates that the physical state of persons with weakened health is significantly correlated with the state and the abilities of their motor function (Kuzmin, Kopylov, Kudryavtsev, Galimov, & Iermakov, 2015; Pryimakov A., Docenko, Pryimakov E, & Eider, 2010), the level of development and interrelationships of motor qualities (Docenko, 2011; Nazarenko, 2011), the quality of managing motions of different coordination structure (Docenko, 2011; Schnabel, 1994). However, a sufficient scientific information about the reserves of motion management system in persons with health deviations is not yet available. Motor activity, which is based on numerous versatile motions of different coordination structure (Bernshteyn, 1947; Golubev, Davidenko, Mozzhukhin, & Shabanov, 1987), is one of the most significant natural factors and the conditions of healthy lifestyle (Fairclough, 2006; Kobza, 1999; Docenko, 2011, Nazarenko, 2001; Hasl, & Axt-Gadermann, 2014).

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Due to insufficient illumination of studied problem, ***the objective of the given study*** was to examine the reserve capacities of the systems of managing motions of different coordination structure in female students with health deviations and their enhancement by physical culture means. Particular tasks of work included: 1) study of reserve capacities of motion management systems in female students with weakened health; 2) analysis of elaborated physical education program impact on motor capacities and physical state of female students of special medical group.

To solve the tasks set in the study, the regularities of managing motions of different coordination structure have been examined in female students of control (CG) and experimental group (EG) of special medical department of V. Lazaryan Dnepropetrovsk National University of Railroad Transport.

Methodology, material and methods.

Methodology

Principles of system approach in biology (Sudakov, 1996), theory of motion management (Bernshteyn, 1947; Donskoy, 1991; Ghez, 1985; Enoka, 1994), adaptation to physical loads (Mishchenko, 1990; Pavlov, 2000; Radzievskij, Pryimakov, Oleshko, & Iashchanin, 2002), etc. have formed methodological basis of studies. Authors' views have served as a theoretical basis for experiment organization.

Procedure

The complex of relatively simple methods of studies, substantiated and presented in the literature by different authors (Serhiienko, 2001; Roth K., & Roth Ch., 2009**;** Ivashchenko, Yermakova, Cieslicka, & Muszkieta**,** 2015) was used for the assessment of the reserves of motion management system. Indices characterizing the quality of managing motions of different coordination structure were recorded (Docenko, 2011; Kopeikina, Drogomeretsky, Kondakov, Kovaleva, & Iermakov, 2016; Raczek, Mynarski, & Ljach**,** 2003): a) jumps over skipping rope; b) rhythmic spatial movements of the hand according to the given landmark (at a distance of 10 cm) at a maximum rate; c) precision straight line walking to the given landmark (at 3 m distance) with closed and open eyes before and after vestibular stimulation; d) tennis ball throws at stationary and moving target – at 3 m distance; e) 4x9 m shuttle running; f) reproduction of a ten-centimeter line on a paper by hand with open and closed eyes (using a pencil); g) "Flamingo" balance testing.

In order to increase the motor system reserves, we have elaborated a program of development of coordination capacities for female students with health deviations, referred to special medical group (Docenko, 2011; Pryimakov A., Docenko, Pryimakov E., & Eider, 2010).

It is based on physical exercises of increased coordination complexity with novelty elements. Exercises of local, regional and global character with numerous motor switches/transitions (Pryimakov A., Docenko, Pryimakov E., & Eider, 2010; Moosmann, 2008; Neumaier, 2009) were used with presence and partial deprivation of sensory information. It also contributed to the increase of session motor density at the first and the second course in EG and CG to 81.4 % and 83.37 %, and to 76.24 % and 76.4 %, respectively.

The complexity of physical exercises was increased at the expense of changing their spatial, temporal and dynamic parameters (Docenko, 2011; Fairclough, & Stratton, 2006): 1) changes in breadth stance while standing or its mobility in equilibrium exercises; 2) functional deprivation of some sensory systems during performance of precision exercises; 3) combining motor skills; 4) combination of walking with jumping, running and catching the objects; 5) exercise performance in response to a signal or within limited interval; etc.

Musical accompaniment of exercises and means of aerobics, dancing elements, playing character of many exercise performance contributed to increased emotional richness and density of sessions (Docenko, 2011; Pryimakov A., Docenko, Pryimakov E., & Eider, 2010).

Participants

The study involved 136 female students of special medical group (SMG) aged 17-19 years. They were divided into 2 groups – control (CG) and experimental (EG). Duration of studies constituted one academic year. Students of CG attended physical education classes in accordance with the State University Program for SMG.

Study protocol was approved by Ethic Committee University. The research was fulfilled in compliance with WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects (2013).

Statistical analysis

Statistical methods and Statistica 12.5 program were used for experimental material processing (Borovikov & Ivchenko, 2006).

Results

Table 1 presents the results of studies of the quality of managing motions of different coordination structure at the beginning and at the end of pedagogical experiment in female students of CG and EG.

Table 1. Indices of the quality of motor regulation in students of experimental and control group at the beginning and at the end of the study

Groups	Indices	Beginning of experiment			End of experiment			% of changes	p
		n	X	±m	n	X	±m		
Experimental group	Experimental group	35	26,0	0,9	35	20,1	0,7	22,5	<0,001
	Error in reproducing 10-cm line on a paper by hand (eyes closed), mm	35	9,0	0,2	35	6,2	0,22	44,8	<0,001
	Skip jumping, number·10 s	54	24,4	0,42	54	26,7	0,35	9,2	<0,001
	Failures during skip jumping, number·10 s	54	0,3	0,10	54	0,1	0,04	72,2	<0,05
	Shuttle running (SR), r	39	10,9	0,09	39	10,5	0,09	3,1	<0,01
	Coordination reorganization during SR, s	39	4,8	0,12	39	5,2	0,09	8,4	<0,01
	"Flamingo" balance testing, s	55	6,0	0,5	56	5,2	0,6	13,4	>0,05
	Tennis ball throwing at a target, points	59	1,8	0,2	59	3,2	0,2	70,6	<0,001
	Total time of 10 alternating finger touches of two circles placed at 10 cm from one another at maximum speed, s	59	5,8	0,1	59	6,3	0,1	9,1	<0,001
Control group	Control group	35	25,9	1,0	35	22,8	0,8	12,5	<0,02
	Error in reproducing 10-cm line on a paper by hand (eyes closed), mm	35	8,5	0,2	35	8,0	0,2	7,4	<0,05
	Skip jumping, number·10 s	34	24,3	0,55	34	26,1	0,63	7,1	>0,05
	Failures during skip jumping, number·10 s	34	0,6	0,15	34	0,1	0,07	81,0	<0,01
	Shuttle running (SR), r	35	11,2	0,07	35	10,9	0,11	2,6	<0,02
	Coordination reorganization during SR, s	35	5,0	0,07	35	5,1	0,12	3,3	>0,05
	"Flamingo" balance testing, s	77	5,9	0,1	69	5,7	0,1	3,6	>0,05
	Tennis ball throwing at a target, points	59	1,9	0,2	59	2,5	0,2	29,6	<0,01
	Total time of 10 alternating finger touches of two circles placed at 10 cm from one another at maximum speed, s	77	5,7	0,1	77	5,9	0,1	3,6	<0,05

Presented in the Table indices reflect the motions of different regulation and coordination structure levels (Bernshteyn, 1947; Ghez, 1985): rubrospinal (speed motions with skipping rope, speed and coordination rhythmic hand motions, "Flamingo" testing), thalamopalidary (precision motions with skipping rope, precision straight line walking under conditions of sensory deprivation), strial (straight line walking under conditions of sensory control, reproduction of 10-cm line on a paper under conditions of partial or complete sensory control, object throwing at a target, coordination reorganization during shuttle running), etc.

Presented results are indicative of the improvement of the quality of managing motions of different regulation levels in students of CG and EG by the end of the experiment. These data suggest that the experimental program applied in EG turned to be more efficient than the standard university program in CG. While before the experiment EG and CG did not differ in studied indices, then after its completion the students of EG had an advantage in straight line walking to the given landmark with open eyes (13,4%, $p<0,05$), precision throwing at a target (21,9%, $p<0,001$), precision of 10-cm line reproduction (29,0%, $p<0,001$), speed of rhythmic pendulum-like hand motions (6,3%, $p<0,01$), equilibrium coordination at reduced breadth stance while performing "Flamingo" testing (9,6%, $p<0,01$), number of executed motions and failures while jumping over the skipping rope per unit of time. Tennis ball throwing at a target reflected better coordination and extrapolational forecasting in EG students as compared to those of CG at the end of the experiment.

With positive shifts in all studied indices, a statistically insignificant positive tendency in coordination reorganization during 4x9 m shuttle running (time of realignment while changing the direction of motion), "Flamingo" testing and skip jumping has been noted in CG. The greatest changes during pedagogical experiment occurred in indices reflecting the activity of the higher levels of regulation – C and D (during straight line walking to the given landmark, 10-cm line reproduction, ball throwing at a target, shuttle running). Less significant shifts were observed in exercises regulated at the lowest motor levels (skip jumping, rhythmic pendulum-like hand motions, "Flamingo" testing). They were stable and less subjected to changes by means of physical exercises. Analysis of findings reflecting specificity of managing *cyclic locomotor movement* along the given trajectory (straight line walking at 3 m distance to the given landmark) demonstrated the improvement of motor regulation quality in all registered directions in CG and EG by the end of the experiment: forward, backward, to the left and to the right (Fig. 1).

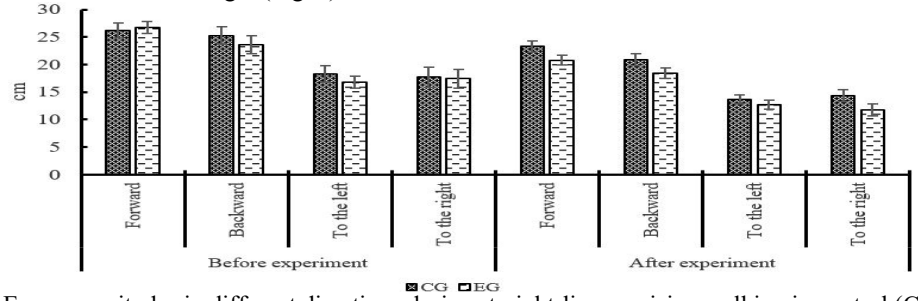

Fig. 1. Error magnitudes in different directions during straight-line precision walking in control (CG) and experimental (EG) group before and after the experiment

While before the beginning of the experiment the differences in the quality of motion management were statistically insignificant, then after its completion the advantages in motor regulation of EG students have been manifested at the end point in all registered directions (Fig. 1).

Error magnitudes in anteroposterior direction have decreased by 14 % and 22.6 % (P<0,01) in CG and EG, respectively, whereas those in lateral directions – by 22,2 % (P<0,01) and 28 % (P<0,01), respectively.

Analysis of sensory control peculiarities during managing cyclic locomotor movement (Fig. 2) shows the improved quality of motor regulation in pedagogical experiment in CG while using visual and auditory feedback channels, whereas in EG – during task performance from memory (MM).

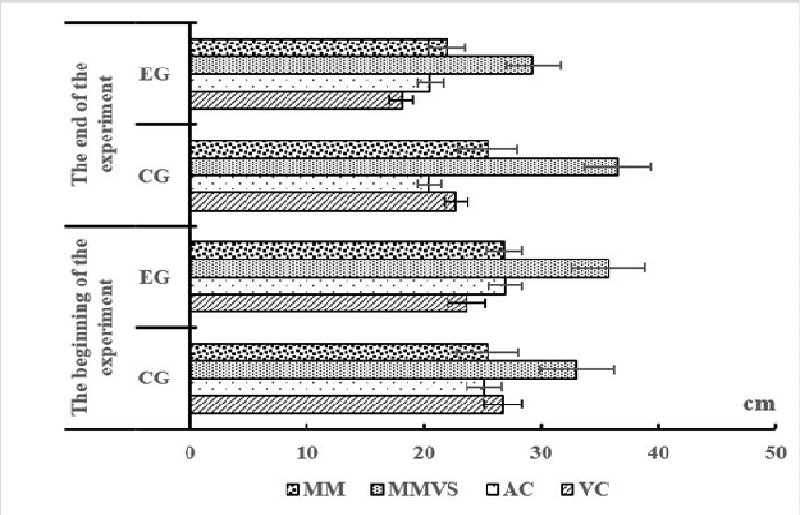

Fig. 2. Deviations during straight line walking in presence of visual (VC) and auditory (AC) feedback, from memory (MM) and after vestibular stimulation (MMVS) in students of control (CG) and experimental (EG) group at the beginning and at the end of the experiment.

More expressed positive shifts have occurred in EG during motion performance in all studied tests: with participation and functional deprivation of visual (VC) and auditory (AC) sensory systems, on the basis of motor memory before (MM) and after vestibular stimulations (MMVS). Increased precision of motion in EG indicates improved coordination of movement and functional state of proprioceptive system, more perfect sensory interrelations, increased interference resistance of a skill and enhanced role of program mechanism in the system of managing locomotor voluntary movement.

Increased interference resistance of a skill in EG to vestibular stimulations reflects the formation of compensatory responses in the process of training, which dampen interferences in the presence of distracting factors.

Interference resistance of a skill in CG to vestibular stimulations and the role of program mechanism in managing precise locomotor movement have changed insignificantly during the experiment.

Presented in Table 2 data reflect the role of the major sensory systems during managing precision motion with involvement of *fine motor skills* (10-cm line reproduction on a paper under different conditions of sensory provision) in female students of CG and EG before and after pedagogical experiment.

Table 2. Error magnitudes during 10-cm line reproduction with different involvement of sensory systems before and after pedagogical experiment (mm)

Conditions	Stat. parameters	Experimental group				Control group			
		VC	AC	MM	Average for all	VC	AC	MM	Average for all
Before experiment	X	6,7	8,4	11,9	9,0	7,5	7,4	10,6	8,5
	±m	0,27	0,30	0,43	0,20	0,3	0,3	0,4	0,2
	n	465	477	459	1401	576,0	568,0	568,0	1712,0
After experiment	X	4,5	5,3	8,8	6,2	6,7	7,8	9,9	8,0
	±m	0,27	0,24	0,51	0,22	0,3	0,3	0,4	0,2
	n	370	367	374	1111	539	514	449	1502
% of changes		48,9	58,5	34,9	44,8	11,9	-5,1	7,1	7,4
t-criterion		5,80	8,03	4,60	9,25	1,78	0,88	1,19	2,04
P		<0,001	<0,001	<0,001	<0,001	>0,05	>0,05	>0,05	<0,05

Note: VC – visual correction; AC – auditory correction; MM – motor memory.

Carried out experiment have allowed to reveal the positive changes in different conditions of sensory provision for local motion in EG students: with involvement of visual feedback channel (VC), while informing the subject about the magnitudes of committed errors via auditory feedback channel (AC) (performance with closed eyes), on the basis of motor memory (MM) with proprioceptive afferentation involvement.

Positive tendency to increase of the quality of managing precision motion from memory (MM) and during the usage of visual information (VC) has been manifested in CG. Meanwhile, managing precision motion with auditory sensory system involvement has tended to deteriorate.

The role of visual sensory system in correctional adjustment of performed motions is crucial both at the beginning and at the end of the experiment in both groups, whereas that of auditory one slightly decreases by the end of the experiment. It is noteworthy that in EG the sensory information from distant receptors tended to "adjust" the program of motor regulation more qualitatively at the so-called "stage of afferent synthesis" (Rovny, 2001; Sudakov, 1996) – before the repeated reproduction of motions. Besides, by the end of the experiment the students of this group more qualitatively performed motions from memory and on the basis of proprioceptive afferentation during functional deprivation of visual and auditory sensory systems.

Reduction of errors during motion management with involvement of fine motor skills under different conditions of sensory control and hindrances points to the fact that the annual pedagogical process has contributed to the improvement of sensomotor interrelations and the decrease of sensory systems sensitivity threshold to the perception of deviations from specified target in EG students to a greater extent.

Motor sensory system as a channel of internal feedback provided the motor centres with more qualitative information about the degree and duration of muscle contractions and joint displacements during precision motion performance.

Analysis of learning process demonstrated the speed-up of mastering precision motion in EG students with auditory feedback available. While before the studies, the visual reorganization of motion in EG students continued to 6 repetitions, then at the end of the experiment 4 repetitions were enough to transit to relatively autonomous (program) mechanism of motor regulation and stabilization of motion with less performance errors.

Visual adjustment of motion in CG before the studies continued to 7 repetitions, whereas after the annual experiment 6 repetitions were enough. It is noteworthy that both the efficiency of sensory systems involvement in correction process and the efficacy of pedagogical program influence on speed of mastering and quality of managing the local precision motion were manifested to a greater extent during the first half of performed test. The advantage of EG in error minimization has been manifested to a greater extent during the first reproductions (from the 1st to the 8th) of precision motion. During the subsequent reproductions (from the 9th to the 16th) the errors have been minimized and stabilized in both groups leading to less significant difference between EG and CG. It is also specific that the leading role of vision as the feedback channel has been maintained in students of EG and CG within the whole testing both at the beginning and at the end of the experiment. It is confirmed by high negative coefficients of correlation between the number of repetitions and the magnitude of committed errors in the presence of visual feedback channel (Table 3).

Table 3. Model characteristics of local motion (Y) precision dependence on the number of repetitions (x) with vision involvement at the beginning (1-8 reproductions) and at the end (9-16 reproductions) of testing in pedagogical experiment.

Groups	Conditions	1-8 reproductions		9-16 reproductions	
		r*	Y*	r	Y
Experimental group	Beginning of experiment	-0,784, p<0,02	10,24-0,606x	-0,905, p<0,0003	7,38-0,399x
	End of experiment	-0,744, p<0,03	8,036-0,687x	0,113, p>0,05	3,41+0,056x
Control group	Beginning of experiment	-0,901, p=0,002	12,965-0,928	-0,850, p<0,01	13,257-1,136x
	End of experiment	-0,336, p>0,41	6,98-0,139	-0,495	5,33-0,092x

*Note: r – correlation coefficient, Y – regression equation.

High association between the number of repetitions and motion precision has been maintained at the end of the experiment in EG during the first (initial) stage of motion mastering (from the 1st to the 8th repetition), whereas during the second one (from the 9th to the 16th repetition) it has decreased significantly. With minor reproduction errors (Table 2) it indicates the transition to program mechanism of motion management at the second stage. Visual information in CG has been less efficiently used for motion correction. Students of this group failed to improve the motion quality as compared to the beginning of the experiment (Table 2).

Lower values of correlation coefficients in the face of relatively high magnitudes of committed errors in CG as compared to EG, are indicative of relatively low speed of formation of local motion management program, slowness of transition from external (visual and auditory) to internal (proprioceptive) feedback in order

to provide current correction and insufficient compensation reserves in the presence of hindrances in CG students.

Higher quality of precision motion mastering with involvement of sensory systems at the first half of performed testing is also confirmed by average meanings of obtained results according to both each feedback channel and averaged error magnitudes during reproducing precision motion after its stabilization. They constituted 6,9±0,2 mm and 4,8 ±0,2 mm for students of CG and EG, respectively. The difference was statistically significant ($t=6,58$; $P<0,01$).

Discussion

Collegiate age is characterized not only by the completion of the period of body growth and development. Due to intensive process of education, the students master theoretical knowledge and practical skills including in the course of motor activity during physical education classes. This may be considered as the important factors stimulating the increase of student body reserve capacities, on the whole, and their motor system, in particular. That is, the major criteria of human body reserve capacities should include not only the ability to perform the work of a particular volume, duration and intensity but the capacity for learning, mastering motions and their efficient executing in body optimum regimen (Bosenco, Samokih, Strashko, Orlik, & Petrovsky, 2013; Yukhimenko, 2007).

In the course of the experiment the motions of different regulation and coordination structure levels (Bernshteyn, 1947; Docenko, 2011; Gurfinkel', & Levik, 1990) have been studied: rubrospinal (speed motions with skipping rope, speed and coordination rhythmic hand motions, "Flamingo" testing), thalamopalidary (precision motions with skipping rope, precision straight line walking under conditions of sensory deprivation), strial (straight line walking under conditions of sensory control, reproduction of 10-cm line on a paper under conditions of partial or complete sensory control, object throwing at a target, coordination reorganization during shuttle running).

Taken as a whole, the findings reflect physical exercise positive impact on the quality of managing motions of different coordination structure by female students of special medical department.

Our elaborated experimental program (Docenko, 2011; Pryimakov et al., 2010) provided high density of classes, increased the quality and the reliability of motor regulation, the reserve capacities of student system of motion management. More expressed positive character of motor function changes in students of EG reflects the efficiency of elaborated experimental program for enhancement of the reliability of managing the studied motions of different regulation levels. The efficiency of elaborated experimental program may be confirmed by the fact that after the completion of the experiment in students of EG better coordination capacities have been manifested while managing precision motions as compared to those of CG ($t=2,43$, $P<0,001$). The most expressed positive shifts in students of EG have been noted during performance of local (10-cm line reproduction), regional (straight line walking) and global (shuttle running, throwing at a target) precision motions. The highest increase of the result in tennis ball throwing at a target under the influence of experimental program was observed in students of EG. The results reflect the improvement of hand-eye coordination and the increase of capacity for extrapolational prediction of EG students. Analysis of the quality of motion management under different conditions of pedagogical experiment, their comparison with literature data have demonstrated low variability of general regulations of mastering motions of different regulation levels (A, B, C, D) and coordination structure as well as the role of sensory systems (Bernshteyn, 1947; Docenko, 2011; Pryimakov, Kozetov, & Eider, 2008; Wilmore, & Costill, 2005).

As far as the majority of tests envisaged performance of motions under complicated conditions (sensory restrictions or stimulations, speed, precision) the improvement of motor regulation quality under these conditions, most expressed in EG students, may be considered as a sign of enhancing the reserve capacities of functional system with specific target function. This also reflects the improvement of compensatory mechanisms for maintaining the reliability of motor function, which provides motion execution with the given parameters under the influence of distracting factors and hindrances.

Conclusions

1. Methodical and organizational approaches applied for physical education provision of female students with health deviations permit to increase motor system reserve capacities and to demonstrate higher results in motor tests.

2. Increase of the quality of managing motions of different coordination structure in the presence of distracting factors by the end of the experiment reflects the growth of compensatory reserve capacities of motor system, providing the reliability and the quality of student motor regulation.

3. Under the action of distracting factors and hindrances, the role of external feedback in compensating disorders in coordination of motions and transiting to program mechanism of motion management tends to increase.

4. Speed of motion mastering, efficiency of compensatory responses, stability and reliability of maintaining qualitative parameters of motions within optimum range in presence of distracting factors and

hindrances, increase of the role of program mechanism in the system of voluntary motion management under stable conditions of its realization may be considered as the criteria of the reserve capacities of subjects' motor system.

5. More expressed positive changes in the course of the experiment occurred in indices reflecting the activity of the higher regulation levels. In exercises regulated at the lower motor levels, the shifts were less significant, more conservative and less subjected to variations as a result of physical exercises.

Conflict of interests. The authors declare that there is no conflict of interests.

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