

Increasing the reserves of the control system for cyclic locomotor precision motions in female students of a special medical group

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Abstract.

Objective: Increasing the reserve capacities of the control system for cyclic locomotor precision motion in female students of a special medical group in the process of physical education. **Material and methods:** The study involved 85 to 135 female students of the special medical group (SMG) aged 17-23 years. They were divided into two groups - control (CG) and experimental (EG). The students of the CG attended classes in PE in accordance with the state university program for the SMG. The program aimed at increasing the reliability of the motion control system of different coordination structures was additionally realized in the EG. It was based on physical exercises of increased coordination complexity with elements of novelty. Exercises of local, regional, and global character with a large number of motor switches with participation and partial deprivation of visual and auditory afferentations were used in the classes. As a testing exercise, the SMG students performed straight line walking to the target with eyes open and closed, with participation and exclusion of auditory feedback, and from memory - before and after the Yarotsky vestibular test. The duration of the study was one academic year. **Results:** It was revealed that the mastering of control for precision motions in the EG was characterized by an improvement in the quality of motor regulation, an increase in the speed of transition to the program regulation mechanism in stable conditions of precision motion realization, an increase in the power of compensatory readjustments to preserve the reliability of motor function in complicated conditions - under the action of confounding factors and hindrances. This indicated an increase in the reserve capacities of the motion control system. **Conclusions:** The main criteria of functioning reliability of locomotion control system, its reserve capacities are: a) stability of maintaining qualitative motion parameters within an optimum range under the action of confounding factors and hindrances; b) transition to the program mechanism of motion regulation in standard conditions of the motor program realization; c) reduction of a role of visual and auditory sensory systems during locomotion precision control in standard conditions; d) minimization of sensory and sensorimotor interrelations during voluntary precision motion control in standard conditions.

Keywords: female students, special medical group, control, motion, reserves.

Introduction

The issue of increasing and mastering the functioning of reserves (FR) of the motion control system of different coordination structures refers to one of the inadequately treated problems of system physiology, medicine, theory, and methodology of physical education and sport (Golubev et. al., 1987; Gurfinkel & Levik, 1990; Pryimakov et. al., 2016; 2017a; Samokish et. al., 2017).

Even though the general principles and mechanisms of motor control are reflected in the works of various authors (Bernstein, 1947; Gurfinkel & Levik, 1990; Kutlakhmedov, Matveeva, Groza, 2018; etc.), the reserve capacities of the motion control system still remain underreported.

In particular, mechanisms and methods of increasing the reliability of motor regulation as one of the important criteria of FRs of motion control system are insufficiently studied like the FRs of a motion control system in individuals of different sex, age, sports specialization, physical condition, and health.

Being one of the human body FR components, the reserves of the motion control system are relatively poorly elucidated from the standpoint of mechanisms of increasing the reliability and quality of motor control in extreme conditions of life activity both in healthy individuals (Golubev et al., 1987; Davidenko, Mozzhukhin, Telegin, 1987; Becker et al., 2015; Pryimakov et al., 2021b) and those with health-related abnormalities (Docenko, 2011; Krivoshchekov, 2012; Kopeikina et al., 2016; Pryimakov et al., 2017a; 2021).

Motor activity is one of the natural factors of a healthy lifestyle (Docenko, 2011; Kuzmin et al., 2015; Kutlakhmedov, Matveeva, Groza, 2018; Pryimakov et al., 2017a;), as well as an important factor in increasing the reserve capacity of the motor system during engagement in physical culture and sports (Radzievsky et al., 2002; Bosenko et al.,

2013; Mikhailova. et. al, 2019; Averin, 2021). Health, as a biological category, reflects the body ability to preserve and restore functional reserves expended in the process of adaptation to changing environmental conditions and physical loads (Krivoshechekov, 2012; Kurzanov, Zabolotskikh, Kovalev, 2016; Kurzanov, 2016; Averin, 2021).

The reserves of the motion control system are determined both by the tension of the body regulatory systems and the quality of compensatory rearrangements providing reliability of motor control under the action of confounding factors and hindrances in extreme conditions of muscular activity (Bernstein, 1947; Davidenko, Mozzhukhin, Telegin, 1987; Prysiazhniuk et. al., 2021).

The diversity of motor skills that a person masters in the course of life characterizes his/her motor system reserves. They allow solving a motor task through different, interchangeable ways (Bernstein, 1947; Gurfinkel & Levik, 1990).

The principle of equifinality (stability), reflecting the multivariate ways of solving one and the same motor task (Ogurtsov, 2013), is one of the key systemic principles of motor control reliability in complex conditions of muscular activity (Bernstein, 1947; Kutlakhmedov et. al., 2018; Prysiazhniuk et. al., 2021).

Natural locomotor motions with small muscle tension, as well as local precision motions, figure large among the variety of mastered movements in humans.

The reserves ensuring the reliability of such motion control in extreme conditions of life activities have also not been sufficiently studied so far. The reserves and mechanisms of increasing the reliability of local and regional motion control in persons with health disorders at the stage of remission are also understudied.

At the same time, local motions, as well as locomotions without great muscular tension (for instance, Nordic walking) are often used as an effective method for the functional reserves' restoration of the human body (Averin, 2021).

However, the reserves of the control system of local and regional motions, including precision ones, as well as the means of their restoration and enhancement in persons with health impairments are inadequately treated in the literature.

The objective of the present study is to improve the reserve capacities of the cyclic locomotor motion control system in female students of the special medical group in the process of physical education.

Material and methods

Participants. Female students of the National Pedagogical University of Railway Transport aged 19-23 years were examined. The study involved 85 to 135 female students of the special medical group (SMG) (students with health disorders at the stage of remission) who were divided into control (CG) and experimental (EG) groups.

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).

Procedure. This paper analyzes the research material reflecting the reserves of the cyclic locomotor control system of female students during straight line precision walking to a given landmark at a distance of 5 m from the starting line.

The SMG students performed straight line walking to the target with eyes open and closed, with participation and exclusion of auditory feedback, and from memory - before and after the Yarotsky vestibular test (Docenko, 2011).

Motor control precision was assessed according to the values of deviations (in cm) from a straight line in the frontal and the sagittal planes - when stopping at the end (target) point.

The students of the CG attended physical education classes in accordance with the state university program for the SMG. The program aimed at developing coordination capacities, increasing the reliability and the reserves of the motion control system was additionally implemented in the EG (Docenko, 2011; Pryimakov et., all., 2016; Pryimakov et al, 2017b).

It was based on physical exercises of increased coordination complexity with elements of novelty.

Exercises of local, regional, and global character with a large number of motor switches (Docenko, 2011; Pryimakov et., al, 2016) with participation and partial deprivation of visual and auditory afferentations were used in the classes.

The above contributed to an increase in motor density of sessions at the first course in EG and CG up to 81,4% and 76,24 %, respectively, whereas at the second course up to 83,37%, and 76,4%, in EG and CG, respectively.

The complexity of physical exercises was increased at the expense of changing their spatial, temporal, and dynamic parameters (Docenko, 2011):

- 1) changes in the standing support area or its mobility in balance exercises;
- 2) functional deprivation of individual sensory systems in mastering and controlling precision motions;
- 3) combining motor skills;
- 4) combinations of walking with jumping, running, and catching objects;
- 5) performing exercises at a signal or within a limited time; etc.

The musical accompaniment of exercises and means of aerobics, dance elements, the game nature of the performing many exercises contributed to the enhancement of the emotional intensity and density of the lesson. The duration of the study was one academic year.

Statistical analysis. The package of STATISTICA 13,5 statistical programs was used for the experimental material processing (Borovikov & Ivchenko, 2006).

Results

The data presented in Figure 1 reflect the peculiarities of locomotion control in the process of the movement program realization during "switching off" the visual and auditory feedback channels in female students of CG and EG. Straight line walking under these conditions up to the target was performed with the dominance of the kinesthetic and vestibular sensory systems.

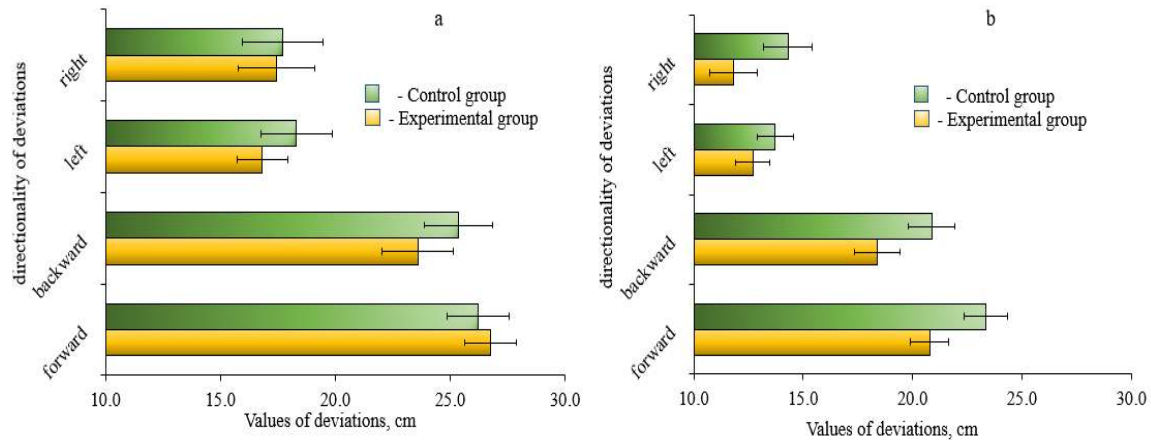


Fig. 1. Values of deviations in sagittal (forward, backward) and frontal (right, left) directions during a straight-line walking to the target in the control and experimental groups, before (a) and after (b) the experiment (see explanation in the text).

The values of the committed errors (Fig. 1), indicate that the quality of control of cyclic motion along a given trajectory to the target located 5 m from the starting line, is improving in both groups by the end of the experiment.

The reduction of deviations in the end point under conditions of visual and auditory control exclusion reflects the enhanced role of the program mechanism in controlling the precise locomotor motion (Rokotova, 1980; Pryimakov et. al., 2017) and the increase in the quality of motor program realization by the end of the experiment. When visual and auditory control is excluded, the kinesthetic and vestibular sensory systems become the key feedback channels in motor program correction (Docenko, 2011).

It was found that in both groups the motions are better corrected in the frontal plane.

In the course of the experiment, the values of errors committed in the lateral (frontal) directions decreased in the CG and the EG by 22.2% ($P < 0.01$) and 28% ($P < 0.01$), respectively, whereas in the sagittal direction - by 14% and 22.6% ($P < 0.01$).

While the differences in the quality of cyclic motion control between CG and EG were statistically insignificant at the beginning of the study, then at the end of the one-year experiment the advantage of EG students was obvious in both sagittal and frontal projections (Fig.1).

This indicates improved interrelations of tactile, proprioceptive, and vestibular analyzers during the realization of locomotor precise motion in the complicated conditions of maintaining a vertical posture and the executed motion: at the deprivation of visual and auditory afferentations (Gurfinkel, Kotz, Schick, 1965).

To clarify the criteria and mechanisms of locomotion improvement in the course of the experiment, the role of individual sensory systems in motion control was analyzed.

The data presented in Table 1 indicate that in the EG improvement in the quality of motor regulation occurs in all variants of the test used: with the participation of the visual and auditory sensory systems, and in the conditions of performing a movement from memory, except for the motion performed from memory after a vestibular stimulus on the basis of kinesthetic afferentation (MMVS).

Table 1. Deviation during straight line walking with and without visual and auditory feedback, and with vestibular stimulation in the EG before and after the pedagogical experiment

Experiment conditions		Statistical parameters	VC*	AC	MMVS	MM
Beginning of experiment	Forward-backward	$\bar{X}$	23,6	26,9	35,7	26,8
		$\pm m$	1,6	1,4	3,3	1,5
		n	135	135	85	85
	Left-right	$\bar{X}$	11,7	24,6	78,4	13,3
		$\pm m$	1,0	2,0	6,9	1,5
		n	135	135	85	85
End of experiment	Forward-backward	$\bar{X}$	18,1	20,5	29,3	21,9
		$\pm m$	1,0	1,1	2,3	1,5
		n	135	135	85	85
	Left-right	$\bar{X}$	10,1	16,1	65,2	8,9
		$\pm m$	0,8	1,3	6,2	1,2
		n	135	135	85	85
Significance of differences		T _{forward-backward}	2,91	3,61	1,59	2,29
		p	<0,01	<0,01	>0,05	<0,01
		T _{right-left}	1,25	3,65	1,43	2,28
		p	>0,05	<0,01	>0,05	<0,01

*VC – motions performed with visual correction; AC– motions performed with auditory correction; MMVS – motions performed on the basis of motor memory after vestibular stimulations; MM – motions performed on the basis of motor memory.

In the CG, improvement of motor regulation quality in the experiment occurs only with the use of visual and auditory feedback channels (Table 2).

Table 2. Deviation during straight line walking with and without visual and auditory feedback, and with vestibular stimulation in the CG before and after the pedagogical experiment

Experiment conditions		Statistical parameters	VC	AC	MMVS	MM
Beginning of experiment	Forward-backward	$\bar{X}$	26,7	25,1	33,0	25,4
		$\pm m$	1,0	1,5	3,2	2,6
		n	132	132	88	88
	Left-right	$\bar{X}$	12,4	27,6	70,4	10,0
		$\pm m$	1,0	2,5	8,6	1,5
		n	132	132	88	88
End of experiment	Forward-backward	$\bar{X}$	22,7	20,4	36,5	25,4
		$\pm m$	1,0	1,0	2,9	2,5
		n	132	132	88	88
	Left-right	$\bar{X}$	11,0	18,8	71,9	10,3
		$\pm m$	0,7	1,3	7,1	1,5
		n	132	132	88	88
Significance of differences		T _{forward-backward}	2,12	2,61	0,81	0,00
		P	<0,01	<0,01	>0,05	>0,05
		T _{right-left}	1,15	3,12	0,13	0,14
		P	>0,05	<0,05	>0,05	>0,05

Note: see Table 1 for symbols and abbreviations.

In the EG, the most pronounced positive shifts during motion execution occurred in the lateral directions (in the frontal plane) under the conditions of using the auditory feedback channel for motion correction, as well as under the conditions of implementing a motor program from memory.

These changes are indicative of: a) increased role of program mechanism in locomotor motion control; b) increased skill interference tolerance; c) improved functional state of the proprioceptive sensory system; d) more perfect sensory interconnections in the system of locomotor voluntary motion control.

The results of the experiment presented in Tables 1-2 reflect the different role of sensory systems in the improvement of cyclic precision motion control by the end of the experiment both in CG and EG students.

In the CG, the motor regulation quality improved with the use of visual (VC) and auditory (AC) feedback channels for movement correction. Changes in the CG by memory were not statistically significant.

This suggests that the program of precise locomotor motion functions without distant afferentation (based on a fixed program and internal feedback) in the CG female students less qualitatively than in those of the EG. In general, in both groups, during straight line walking, the degree of deviations in the frontal plane decreased to a greater extent than in the sagittal plane (Tables 1-2).

Resistance to vestibular stimuli did not change significantly in both groups. Compensatory responses reducing the expressiveness of vestibulosomatic reactions and the manifestation of discoordination during straight line walking after the Yarotsky test were insufficiently effective by the end of the experiment.

Discussion

Our studies revealed that straight line walking with eyes open and closed, before and after vestibular stimuli (Yarotsky's test) is a highly effective test to assess the coordination capacities of students when performing this type of motions under complicated conditions (Pryimakov et al., 2017a).

The testing algorithm allowed determining the role of proprioceptive, visual, and vestibular sensory systems and their interactions in the correction of walking to a given landmark in different subjects in the dynamics of the experiment (Pryimakov et al., 2017b).

In the course of studies, a positive impact of a complex program of physical exercises on coordination rearrangements in the system of cyclic locomotion control of female students of CG and EG was revealed.

The increased motor density of classes at a relatively low intensity of performed exercises, a large number of motor switches, the use of elements of shaping with musical accompaniment resulted in the quality improvement of locomotor motion control of the CG students. The quality improvement of motor control was manifested in the reduction of deviations in the sagittal and frontal planes during straight line walking to the target under conditions of partial deprivation of the visual and auditory sensory systems, before and after vestibular stimuli. The increase in the interference resistance of motor skill to the action of confounding factors and hindrances was most pronounced in female students of the EG.

This reflects the positive role of the experimental program in increasing the reliability of compensatory rearrangements minimizing deviations during straight line walking under the impact of confounding factors and hindrances. Deviation minimization during walking under conditions of sensory restrictions can be considered as one of the functional reserve criteria of the locomotor motion control system in female students with health-related disorders. This is also a reflection of the principle of the least interaction in the interconnection of sensory systems during cyclic locomotion precision control (Pryimakov et al., 2020).

The motor coordination improvement during cyclic locomotion control under complicated conditions is characterized by the transition to a program mechanism of regulation that weakly depends on external feedback signals under standard conditions of motor task realization (Rokotova et al., 1980; Gurfinkel & Levik, 1990; Pryimakov et al., 2021).

The dominance of the program mechanism, the manifestation of the principle of the least interaction in the interconnections of sensory systems, manifested during locomotion under stable conditions of the mastered motion realization, is in agreement with and complements the studies of Rokotova et al (1980), Pryimakov et al (2021). The motor regulation quality improvement in female students of the SMG by the end of the experiment indicates the increased power of compensatory rearrangements to preserve the reliability of motor function under the action of confounding factors and hindrances and to improve the functional state of the proprioceptive system (Pryimakov et al., 2021).

These studies are in accord with and complement our similar studies conducted on healthy persons (Pryimakov et al., 2020, 2021). The revealed regularities support the concept of cyclic locomotion control (Rokotova et al., 1980) and complement it by determining the reliability criteria of motor control and substantiating the program of cyclic locomotion control improvement for female students with impaired health (Musienko, 2014, Oleksandr Pryimakov et al., 2017b).

The novelty of the findings also consists in the fact that under experimental conditions it was not so much the motion realization program itself that turned out to be "trainable" as its sensory support (sensorimotor interrelations that provided the transition to the program model of cyclic locomotion control) (Pryimakov, Docenko et al., 2017b).

By the end of the experiment, the EG female students had improved motor coordination, increased the efficiency of compensatory responses minimizing deviations in the sagittal and frontal projections under complicated conditions of walking to the target.

During the one-year experiment female students of the EG demonstrated a stable state of health with the dynamics of remission, enhanced resistance to the action of confounding factors and hindrances, improved condition of the motor system.

The positive impact of the suggested exercise program on the motor regulation quality and the health status of female students was manifested in an increase in the number of female students transferred from the special medical group to the preparatory and main groups.

Conclusions

1. Increased motor density of classes at relatively low intensity of performing exercises of different coordination structure with the use of numerous motor switches, elements of shaping, and the musical accompaniment improves the quality of locomotor motion control, motor skill interference resistance, motor system functional reserves of female students with health disorders.

2. The main criteria for the reliable functioning of the locomotion control system, its reserve capacities include:

- a) stability of retention of motion qualitative parameters within optimal range under the action of confounding factors and hindrances (skill interference resistance);
- b) transition to a program mechanism of motion regulation, which weakly depends on sensory information under standard conditions of motor program realization;
- c) decreased significance of visual and auditory sensory systems and their interactions with proprioceptive system during locomotor voluntary motion control;
- d) more perfect sensory and sensorimotor interrelations in the system of locomotor voluntary motion control, one of the most important criteria of which is the principle of the least interaction.

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

References:

- Averin S.O. Physiological mechanisms of functional reserves restoration in persons of II maturity age using Nordic walking. Author's abstract for Ph. D. in Medicine: 03.03.01: 14.03.11. Place of defense: Tyumen State Medical University. Tyumen, 2021. 23 p. (in Russian).
- Becker C.M., Glascoff M.A., Felts W.M., Kent C. (2015) Adapting and using quality management methods to improve health promotion explore. *The Journal of Science and Healing*, 11: 222-228.
- Bernstein, N.A. (1967). The coordination and regulation of movements. Oxford: Pergamon Press.
- Borovikov V.P., Ivchenko G.I. (2006) Prognostication in the system of Statistica in the environment of Windows, Moscow: Finances and statistics. (in Russian).
- Bosenco AI, Samokih II, Strashko SV, Orlik NA, Petrovsky EP. (2013) Evaluation of junior courses students' level of mobilization of functional backlogs at the dosed physical activities at the pedagogical University. *Pedagogics, psychology, medico-biological problems of physical training and sports*, 11:3-9. <https://doi.org/10.6084/m9.figshare.815867> (in Russian).
- Davidenko D.N., Mozzhukhin, A.S., Telegin V.V. (1987). Physiological reserve mobilization during strenuous muscular activity. *Human physiology*, V.13 (1) :127-132. (in Russian).
- Docenko O.M. (2011) raining of special health group girl students' coordination in the process of physical education. *Cand. Diss.*, Kiev. (in Ukrainian).
- Golubev V.N., Davidenko D.N., Mozzhukhin A.S., Shabanov A.I. (1987) Systemic mechanisms of adaptation and mobilization of organism's functional reserves in the process of achievement of highest sportsmanship: monograph. Leningrad: GDOIFK (in Russian).
- Gurfinkel V.S., Kots Y.M., Shik M.L. (1965) Human posture regulation. Moscow: Nauka. (in Russian).
- Gurfinkel B.C., Levik Iu.S. (1990) Central programs and variety of movements. Control of movements. Moscow: Nauka (in Russian).
- Kopeikina E.N., Drogomeretsky V.V., Kondakov V.L., Kovaleva M.V., Iermakov S.S. (2016) Modification of Harvard step-test for assessment of students with health problems functional potentials. *Physical Education of Students*, 4: 44-50. <https://doi.org/10.15561/20755279.2016.0405>
- Krivoshchekov S. G. (2012) Stress, functional reserves and health. *Siberian pedagogical journal*. Novosibirsk: NSPU, 9: 104–109. (in Russian).
- Kurzanov A.N. (2016) Methodological aspects of body functional reserve assessment. *Modern problems of science and education*, 2: 95:102. <http://www.science-education.ru/ru/article/view?id=24402>. (in Russian).
- Kurzanov A.N., Zabolotskikh N.V., Kovalev D.V. (2016) Body functional reserves: monograph. Moscow: Publishing House of the Natural History Academy. ISBN 978-5-91327-403-8. (in Russian).
- Kurzanov A.N. (2015) Functional reserves in the aspect of clinical physiology. *Modern issues of science and education*, 4. <https://www.science-education.ru/ru/article/view?id=20456> . (in Russian).
- Kutlakhmedov Yu.A., Matveeva I.V., Groza V.A. (2018). Biological systems reliability. Teaching guide. Kiev: Fitosociocenter. (in Russian).
- Kuz'min V.A., Kopylov Yu.A., Kudryavtsev M.D., Galimov G.Ya., Ermakov S.S. (2015) Substantiating efficiency of health-related method sessions for students with decreased motor fitness level. *Physical education of students*, 6: 43-49 (in Ukrainian). DOI: <https://doi.org/10.15561/20755279.2015.0606>
- Mikhailova S.V., Poliakova T.A., Semovova S.G., Sidorov B.B. (2019) Characteristics of physiological functions determining the functional reserves of students with varying motor activity level. *Science and sport: current trends*, vol. 7: 2: 74-80. (in Russian).
- Ogurtsov A.P. (2013) System analysis of equifinality and human-sizedness. *Epistemology and philosophy of science*, 3: T.XXXVII: 190-204. (in Russian).

- Pryimakov Oleksandr, Iermakov Sergii, Kolenkov Oleksandr, Samokish Ivan, Juchno Jury (2016). Monitoring of functional fitness of combat athletes during the precompetitive preparation stage. *Journal of Physical Education and Sport*, 16(2), 551–561. DOI: <https://doi.org/10.7752/jpes.2016.02087>
- Pryimakov AA, Eider E, Nosko M.O, Iermakov SS. (2017a) Reliability of functioning and reserves of system, controlling movements with different coordination structure of special health group girl students in physical education process. *Physical education of students*, 2, 84–89. DOI: <https://doi.org/10.15561/20755279.2017.0206>
- Pryimakov A.A., Dotsenko E.N., Kalinsky A.N., Pryimakova O.A. (2017b) Increasing the reserves of the system for control of motions of different coordination structure in students of special medical group. *Scientific journal M.P. Dragomanov NPU. Series 15. Scientific and pedagogical issues of physical culture (Physical culture and sport)*. Issue 9 (91) 17. M.P. Dragomanov Publishing House. Kyiv: 91-96. ISSN 2311-2220 (in Russian).
- Pryimakov A.A, Eider E, Prisiazhnyuk S.I., Mazurok N.S. (2020) Functional reserves of the system of voluntary motion control during strenuous muscular activity. *Scientific herald of K.D. Ushinsky Southern Ukrainian National Pedagogical University*, Odesa, 3 (132): 31-40. DOI: <https://doi.org/10.24195/2617-6688-2020-3> ISSN: 2414-5076 (Print), 2617-6688 (Online)
- Pryimakov Oleksandr, Eider Jerzy, Mazurok Natalija, Omelchuk Olena (2021). Functional reserves and reliability of controlling stereotyped motions of different coordination structures in athletes during muscular activity. *Journal of Physical Education and Sport*, 21(2), 819 – 828. DOI: <https://doi.org/10.7752/jpes.2021.02102>
- Pryisiazhniuk S, Pryimakov O, Iermakov S, Oleniev D, Eider J, Mazurok N. (2021) Influence of weekly physical exercises on indicators of biological age of student's youth. *Physical Education of Students*, 25 (1), 58–66. <https://doi.org/10.15561/20755279.2021.0108>
- Radzievskij AR, Pryimakov A, Oleshko V, Iashchanin N. (2002) On accumulation, condumption and redistribution of functional reserves in human organism. *Nauka v olimpijskom sporte*, 2: 110-119. (in Russian).
- Rokotova N.A., Anisimova N.P., Rogovenko E.S., Shapkov Y.T. (1980). Programing and feedback in regulation of rhythmic motions induced by external signals. *Issues of motion physiology*. Edited by V.S. Gurfinkel.- L.: Science: 25-48. (in Russian).
- Samokish, I., Bosenko, A., Pryimakov, O., Biletskaya, V. (2017) Monitoring System of Functional Ability of University Students in the Process of Physical Education. *Central European Journal of Sport Sciences and Medicine*, 17(1), 73–78. DOI: <https://doi.org/10.18276/cej.2017.1-09> .