VASIL LEVSKI NATIONAL SPORTS ACADEMY
WRESTLING AND JUDO DEPARTMENT

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"IMPROVING THE COORDINATION SKILLS OF HEARING IMPAIRED WRESTLERS"

AUTHOR'S ABSTRACT

OF

DISSERTATION

FOR ACQUISITION OF ACADEMIC DEGREE

"PhD"

IN PROFESSIONAL DIRECTION 7.6 SPORTS

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Sofia 2021

This dissertation is discussed and directed for public justification by an extended scientific college of WRESTLING AND JUDO Department at NSA “Vasil Levski”.

The work consists of 160 standard pages, incl. the bibliography that includes 212 references. It is illustrated with 20 tables and 30 figures.

The public defence will take place on 19.01.2021 from 14.00 in hall A–3 of NSA "Vasil Levski" at a meeting of the specialized scientific jury. The materials for the defence of the dissertation are available in the library of NSA "Vasil Levski".

Note: The numbering of the figures and tables in the abstract corresponds to that of the dissertation.

Introduction

Modern sports science has revealed the basic laws that ensure the management of the training process. These methods are generally valid and are based on the objective laws of sports–scientific knowledge in anatomy, physiology, biochemistry, biomechanics, etc.

One of the basic principles in the science of control of all processes and phenomena (cybernetics) is the requirement for a closed control circuit.

As far as the feedback in the control circuit of the motor apparatus is provided by the sensor system, in case of dysfunction of some of the channels, the initial conditions for training work change.

It is obvious that sports science, in pursuit of the World and Olympic peaks, is not developing in a balanced way and lags behind the ability to adapt training methods for cases where there are physiological disorders of some of its own senses serving the motor analyser.

Purpose

The main objective of the present study is to optimize the sports training of adolescent wrestlers with hearing analyser disorders based on the applied specialized methodology for developing their coordination skills.

Tasks

On the way to solving this main objective, it is necessary to solve gradually the following tasks:

- Analysis of the role of the auditory analyser for motor control.
- The development of a methodology adequate to the problem for the improvement of the training and educational work.
- Conducting experiments to quantify the physical capacity of experienced persons with hearing impairment.
- Formation of statistically indistinguishable groups for carrying out a pedagogical experiment.
- Development of cinematographic and dynamic analysis of the motor tasks set by the methodology.
- Development of a methodology for analogue modelling of statistical biomechanical characteristics.

- Development of a methodology for quantitative assessment of biomechanical characteristics from statistical models.
- Formulation of scientifically substantiated recommendations and directions for development of the new methodical instructions.

METHODS AND ORGANIZATION OF THE STUDY

The study for optimization of the learning process covers a contingent of a total of 34 children between 12 and 14 years of age with hearing impairment and a group of 18 children with normal hearing, with the group of hearing children taking part as a control group only in the study . The age was chosen in view of the stages in the age development of the coordination system and the fact that at this age the sports and technical mastery is not yet fully automated.

This study was conducted from April 2017 to December 2018 and includes three stages:

Findings stage (April 2017) – The problem of scientific research has been identified, the purpose of the research has been formulated, the tasks of the research have been clarified,

Forming stage (May 2017) – Control tests were performed to determine the initial level of development of coordination skills. A set of physical exercises aimed at developing coordination skills has been developed

Control stage (December 2018) – A sports-pedagogical experiment was conducted to evaluate the effectiveness of the methodology. Final testing was performed to establish the level of development of the coordination abilities of students with hearing impairment after the applied training effects.

The following **methods** are used.

a. Study of the special scientific and methodical literature.
b. Methods for assessing the development of coordination skills.
c. Methods for assessing physical development.
d. Laboratory experiments for biomechanical (cinematographic and dynamic) analysis.
e. Statistical methods for evaluating efficiency.
f. Pedagogical experiments.

Methodology for developing coordination skills

The proposed methodology for the development of coordination abilities is consistent with the specifics of the wrestling training process, with the specific features of children with hearing loss, as well as with the sensitive periods for the development of motor skills.

The content of the methodology presents an algorithm for building and improving CS:

- √ reaction speed,
- √ balance,
- √ spatial orientation,
- √ differentiation of movement parameters,
- √ rhythmic ability and
- √ coordination of movements.

After the theoretical analysis of the general, special and specific parameters of the coordination abilities, operational corrections were developed for individualization and optimization of the content of the classes.

Test batteries used:

Coordination abilities tests

1. **Zig zag agility test – ZZAT - *spatial orientation***, speed.
2. **T-test agility - TTA** – speed, ***ability to coordinate***.
3. **Illinois Agility Run Test** –Test with direction change
4. for *Speed of reaction*
5. **Hexagon test agility – HTA** - *Rhythmic ability* and agility.
6. **Romberg test** – the functional state of the vestibular apparatus and the level of static coordination
7. **Orb forward agility test - OFAT** – for the vestibular apparatus.
8. **Step 50 agility test – S50AT** – for the vestibular system and spatial orientation.

Eurofit test battery developed by the European Union was used to determine physical development.

For the needs of the statistical analysis the program SPSS – Statistical Package for the Social Sciences was used

For the needs of the comparative biomechanical analysis the methods of the variational and correlation statistical analyses are applied.

Equipment provision

APAS (Ariel Performance Analysis System) was used for the needs of the research, with the following applications:

- The parallel presentation module (APASView);
- Kinetics module;
- Vector module (Vector

The cinematographic analysis is performed with the help of video computer methodology.

Results and analysis

Theoretical analysis and working hypothesis

The development **of a science-justified** classification structure is considered a fundamental task of any science. This task has led to the establishment of strictly defined independent scientific disciplines (with their own principles and methodology), such as modern sciences taxonomy, botrylogy, cluster analysis, etc. The analysis of motor actions requires the use of a system–structural approach for evaluation and classification of the movement system. The modern biomechanical scheme for system–structural analysis is presented in the following figure.

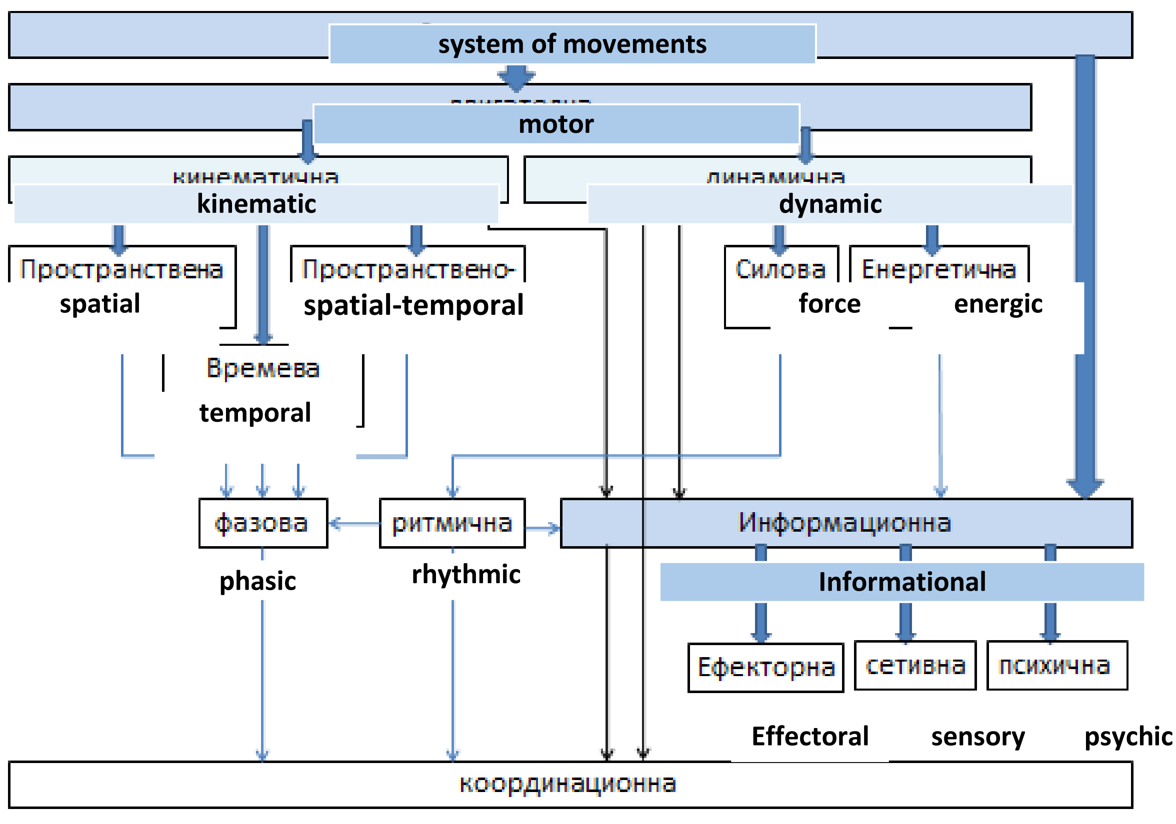

Fig. 2. Biomechanical sch ıctural analysis

The question remains which elements and structural interconnections of the system are broken or modified in case of loss of the auditory analyser. From a physiological and biomechanical point of view, these are mainly the kinematic and especially the information structures.

The effects for the control of motor actions from this problem can be divided into two categories – direct and indirect.

The direct influence refers to the quality of the feedback (afferent) connection in the control circuit of the motor apparatus.

Indirect influences are due to the systemic organization and structural relationship between all biomechanical characteristics.

As far as our main goal depends on the interchangeability of the information channels, the possibilities of proprioception are of special interest for the optimization of the training methodology.

The main skills related to proprioception are:

- **Balance** – improved by the internal control circuit of the motor apparatus.
- **Strength** – the abdominal, back and gluteus muscles are the basis from which most movements start. They are responsible for controlling movements, stabilizing and properly shifting the centre of gravity.
- **Speed** – especially fast reaction in unexpected circumstances.

Proprioreception is the sense through which we know where a certain part of our body is in space. This most often elusive sense can play an extremely important role in the control of the musculoskeletal system, especially for the development of automated motor actions that require the work of our five basic senses, including the auditory analyser. That is why the purposeful development of this information channel with the means of the educational and training work is of special interest.

There are numerous classifications for coordination abilities. For the purposes of this study, we have considered the following main directions in the multidimensional benchmark: general, special and specific. Their characteristic features are as follows:

- *General coordination skills.* Determine the readiness for optimal control and regulation of motor actions of different origin and significance. They are limited by the general physiological laws.

The motor systems in the central nervous system (CNS) that control the movements can be divided into three groups:

- √ volitional movements;
- √ reflex responses;
- √ rhythmic (automated).

In addition, the control is carried out by different structures of the CNS, which are organized in three levels of hierarchy:

1. Spinal cord – controls a number of stereotypical reflexes.

2. Brain – controls the motoneurons in the anterior horns of the spinal cord.

3. Motor zone – the highest level of motor control.

The training process should take into account the existence of the two main motor systems in the CNS:

- √ pyramid system – performs volitional movements
- √ extrapyramidal system (system of the basal ganglia) – realizes the stereotypical movements with reflex character.

Psycho–physiological factors influencing CS are:

1. The functional state of the sensor system;

2. The degree of and nature of action of the various parts of the CNS;

3. The ability of a person to memorize movements and to reproduce them (motor memory).

- ➢ *Special coordination abilities* are the groups of motor actions that are homogeneous in terms of psycho–physiological mechanisms.

These include:

- ✓ cyclic locomotor exercises with a complicated coordination structure,
- ✓ throwing for accuracy,
- ✓ gymnastic and acrobatic exercises,
- ✓ offensive and defensive technical and technical–tactical actions.

In a sense, this type of coordination ability can be defined as a *vertical classification*.

It is obvious that due to the uneven development of psycho–physiological functions it is necessary to distinguish between special coordination abilities and the so–called specific or specific coordination abilities (*horizontal classification*).

- *Specific coordination skills* include:

- the ability for spatial orientation,
- differentiation and accuracy of spatial, force and time parameters;
- reaction speed;
- the ability to restructure motor activities;
- equilibrium stability;
- manageable muscle relaxation.

The structural organization illustrated in Fig. (2) contains a first approximation to the solution of this scientific problem. This is the fact that all biomechanical structures are ultimately reflected in the category of coordination of motor actions.

It is a well–known scientific fact that in all controllable processes in the human body the information flows are two–way. This gives us a reason to scientifically substantiate our working hypothesis:

The generally accepted structural organization illustrated in Fig. (2) must also allow for the existence of feedback, from the coordination structure to the kinematic and dynamic characteristics of the biomechanical system. This feedback regarding the information structure could be successfully used to improve the motor analyser in case of loss or damage of parts of the sensor system.

Experimental analysis

The experimental analysis was performed in three stages as follows:

1. Preliminary – for assessment of physical development and capacity;
2. To assess coordination capabilities and
3. For the needs of the pedagogical experiment and evaluation of the effectiveness of the proposed methodology for training work.

The numerous and diverse composition of the evaluation tests used has become a major problem for the possibility of comparative analysis of different groups of experienced individuals. In order to evaluate the input data and the level of motor abilities of the group of hearing impairments of the hearing analyser compared to the normal hearing, we had to use a generally accepted battery composed of the **following tests:**

1. Sit–Ups in 30 seconds – crunches – endurance of the abdominal and thigh muscles.
2. Sit–and–Reach – flexibility test (using 15 cm from the level of the legs).
3. Standing Broad Jump – a broad jump – test for explosive power of the lower limbs.
4. 6 – minute run, (m) – running 6 min – test for cardiac endurance and lung capacity.
5. Pushups for chest in 30 seconds – pushups – muscular endurance
6. Shuttle Run 3 x 10 meter – shuttle 3 x 10 m/s – shuttle with change of direction – measures speed and agility.

Table 1 Experimental group Results

No.	**Indicators**	**Group**	**Initial testing**			**Final testing**			**α**
			$\bar{X}$	**S**	**V%**	$\bar{X}$	**S**	**%**	<0.05
1	1. Sit–Ups in 30 seconds – crunches	EG	19.8	5.35	27.02	222.25	4.562	20.50	p<0,05
		CG	21.35	4.89	22.9	224.85	4.12	16.57	p>0,05
		p	p>0,05			p<0,05			
2	2. Sit–and–Reach – flexibility test (cm)	EG	2.95	1.45	49.15	3.8	1.96	51.57	p>0,05
		CG	3.26	1.87	57.36	3.9	1.95	50	p>0,05
		p	p>0,05			p>0,05			
3	3. Standing Broad Jump – long jump (cm)	EG	178.25	26.12	14.65	194.6	27.8	14.28	p>0,05
		CG	180.05	17.77	9.86	196.57	16.64	8.46	p>0,05
		p	p>0,05			p>0,05			
4	4. 6–minute run, (m) – run 6 min	EG	901.75	128.04	14.28	3.26	224.85	12.76	p<0,05
		CG	1001.45	105.6	10.54	1208.56	156.01	12.9	p>0,05
		p	p>0,05			p<0,05			
5	5. Pushups for chest in 30 seconds – pushups	EG	18.35	7.32	39.89	21.95	7.14	32.52	p>0,05
		CG	19.75	6.25	31.64	22.14	6.56	29.63	p>0,05
		p	p>0,05			p>0,05			
6	6. Shuttle Run 3 x 10 meter – shuttle 3 x 10	EG	9.58	0.71	7.41	7.94	0.59	7.43	p<0,05
		CG	8.47	0.6	7.08	6.95	0.51	7.33	p>0,05
		p	p>0,05			p>0,05			

The results obtained from the statistical variation analysis of the test data are presented in the following table No. 1

Table 1 presents the results obtained for EG (children with disabilities) and CG (normal hearing) at the beginning and end of the first year. The aim of this initial experiment was to track the development of motor potential in both groups of wrestlers ter the same training regime.

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The changes are illustrated graphically in the following figures.

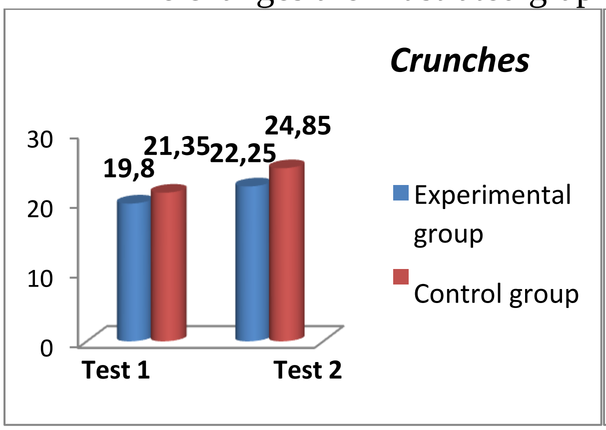


Fig. 6 *Change Sit–Ups indicators in 30s*

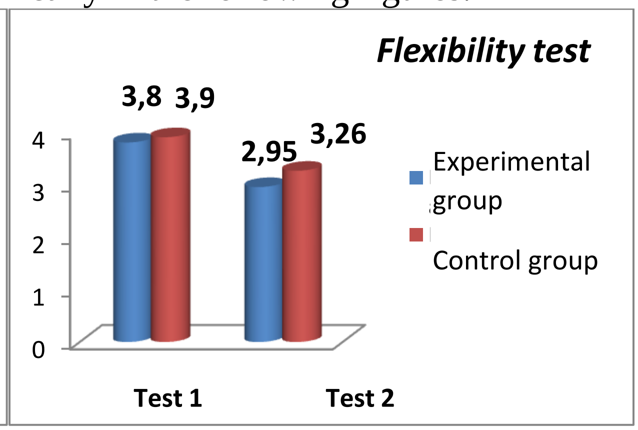


Fig.7. *Changing the flexibility test parameters*

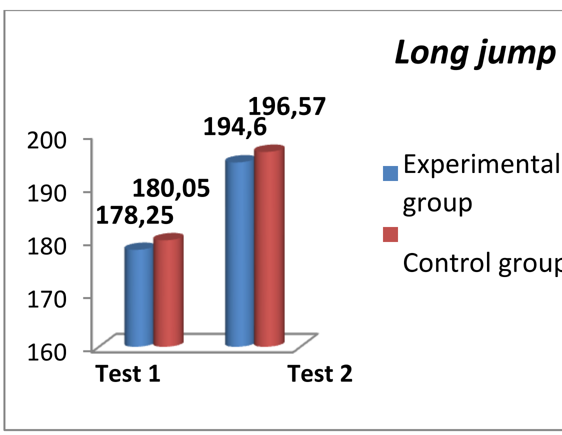


Fig. 8 *Change of the indicators of the explosive force test*

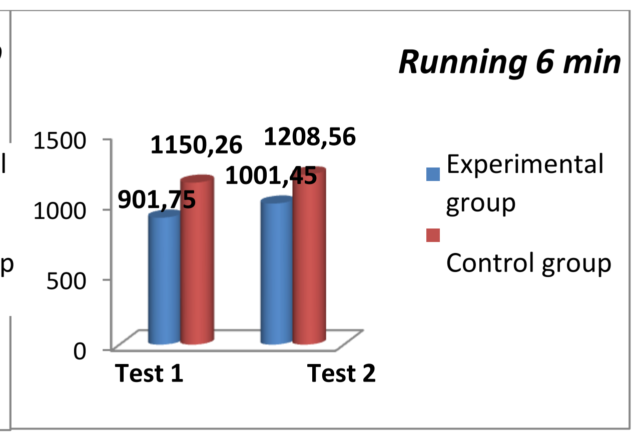
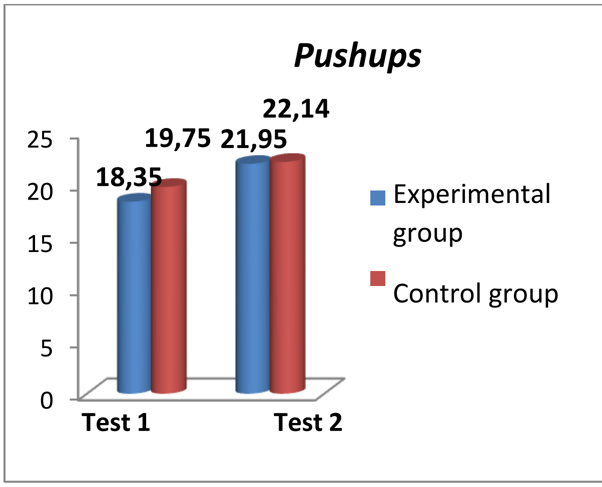


Fig. 9 *Change in endurance test indicators*



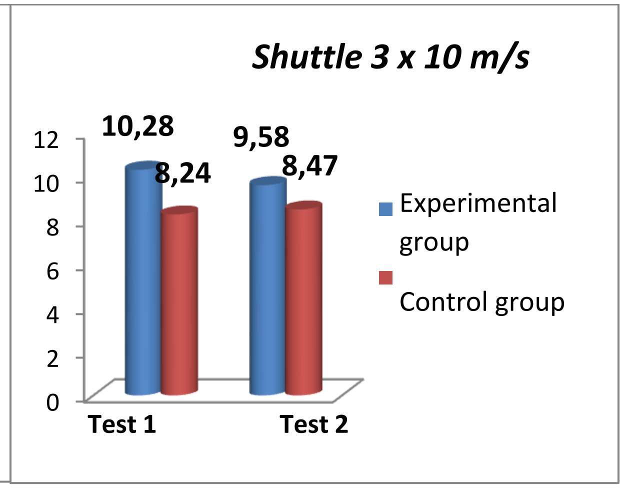


Fig. 10 *Change in indicators in the muscle endurance test*

Fig. 11 *Change of the indicators of the test for speed and agility – shuttle 3 x 10 m / s*

The analysis of the level of general assessment of the physical fitness of the wrestlers in EG at the beginning of the experiment showed that in 55% of the cases this assessment was below the average level for the whole group.

At the end of the experiment, there were significant changes in the structure and distribution of assessments of the level of physical capacity, and the indicators were distributed as follows: the average grades are – 15%, the good are about 70%, with a very good grade they are about 9% and the influenced excellent students are 6%. (Figure 12).

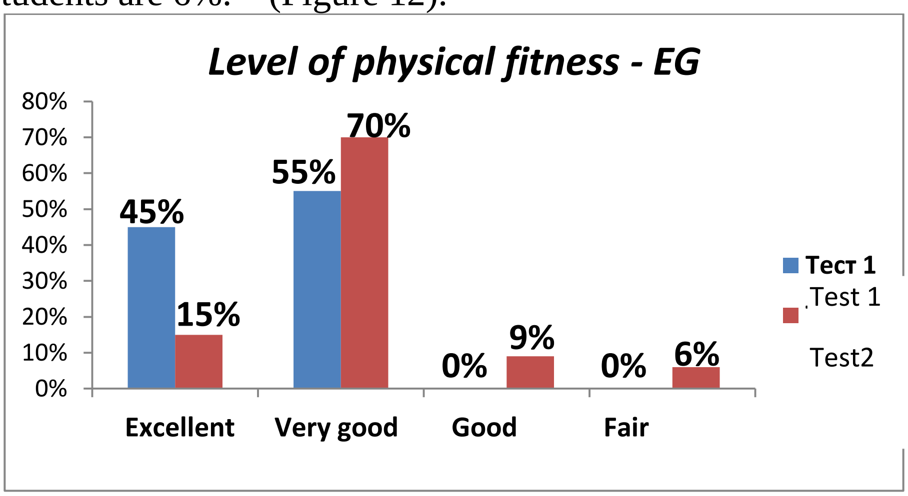


Fig.12 *Change of the indicators for physical fitness of the experimental group (EG)*

As a basis for the subsequent experiments we adopted the generally accepted system – Eurofit. The reason is that it allows for not only longitudinal comparisons in our country, but also a comparative analysis of the state of the problem between different countries, social groups, geographical areas, etc.

At the same time, due to the specific features and characteristics of the object of study, to this main battery, we used an additional set of tests to determine the coordination abilities.

The Eurofit Physical Fitness Test is a set of nine fitness tests that cover flexibility, speed, endurance and strength. The standardized test battery was developed by the Council of Europe

The motor tests are carried out in the obligatory sequence:

1. Flamingos. Measures overall equilibrium stability.
2. Hand touch up to two discs. Measures the speed of hand movement.
3. Lean forward from the seat. Defines flexibility.
4. Long jump with two legs out of place. Measures the explosive power of the legs.
5. Manual dynamometry. Measures static grip force
6. Inclination from seating to back lie Measures the dynamic strength of the muscles along the abdominal wall.
7. Hanging on a lever with folded arms. Measures the static force of the upper limbs and shoulder girdle.
8. Running shuttle – 10x5 meters. Measures running speed and agility.
9. Multi–stage shuttle test – 20–meter shuttle test. It is always held last. Measures maximum aerobic capacity and cardio–respiratory endurance.

Table 2 presents the data from the variation analysis for the whole group of subjects.

Table 2. Variation analysis of the experienced persons

Test	**Flamingos**			**Hand touch**			**Inclination ahead**		
statistics	$\overline{X}$	**S**	**V%**	$\overline{X}$	**S**	**V%**	$\overline{X}$	**S**	**V%**
value	12	5.2	43.33	13.27	2.3	17.33	21.3	7.9	37.089

Test	Long jump			Manual dynamometry			Slope to the occipital leg		
statistics	$\overline{X}$	**S**	**V%**	$\overline{X}$	**S**	**V%**	$\overline{X}$	**S**	**V%**
value	194.6	27.8	14.29	39.8	7.7	19.35	25	4.6	18.4

Test	Hang on a lever			Running shuttle			Multi–stage shuttle test		
statistics	$\overline{X}$	**S**	**V%**	$\overline{X}$	**S**	**V%**	$\overline{X}$	**S**	**V%**
value	17.83	11.2	62.82	20.45	3.5	17.11	6.49	2.8	43.14

Based on these statistics and the laws governing the normal distribution, it is possible to build a mathematical model for the distribution of the number of cases in the intervals for percentile rank. However, insofar as we have the exact experimental data separately for each experimental person, we have compiled tables for the actual distribution of cases in the scale intervals. These experimental data are presented in Tables No. 2 to No. 10.

In the initial data from Table 2, the high coefficients of variation in the tests for balance and strength of the upper limbs are impressive. In the first case, in our opinion, this is due to the different degree of the hearing aid device. For the lever hanging test, the reasons are different. The test is designed so that it does not measure absolute values, but relative ones and the results are strongly influenced by the athletes' own weight. It is known from theory that force is a quadratic function, while weight follows a cubic function of the dimension of the body. In other words, in the presence of different weight categories, this result is completely explainable.

Tables 2 to 10 also present the distribution of cases in the two groups of experienced persons. The extremely high statistical reliability of their indistinguishability in all studied motor qualities is proved.

Table 3. Flamingo test

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	26	22	18	16	14	12	10	8	7	4	4
control	26	22	17	16	14	12	10	8	7	4	4
experimental	25	23	18	15	14	12	10	8	6	4	4

Table 4 Hand touch up to two discs

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	18	16.8	16	15	14	13	13	12	12	11	11
control	18	16.8	16	15	14	13	13	12	12	11	11
experimental	18	16.8	16	15	14	13	13	12	12	11	11

Table 5. Inclination ahead

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	7.8	11	14	16	19	21	23	25	28	32	35
control	7.8	11	14	16	19	21	23	25	28	32	35
experimental	7.8	10	14	16	19	21	23	25	28	32	35

Table 6. Long jump

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	147.9	158.8	169.9	179.6	188.0	194.6	201.8	209.2	218.5	229.9	239.6
control	147.9	158.7	170.2	179.4	187.8	194.7	202.6	209.4	218.8	229.9	239.8
experimental	147.9	158.9	169.6	179.7	188.1	194.6	201.2	209.1	217.5	229.8	239.3

Table 7. Manual dynamometry

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	25.8	28.9	33.5	36.1	38.2	39.8	42.6	44.9	46.8	51.1	53.8
control	26.6	28.7	33.7	36.3	38.2	39.9	42.8	44.9	46.9	51.3	54.6
experimental	24.8	29.1	33.4	36	38.1	39.6	42.4	45.1	46.6	50.9	53.5

Table 8. Inclination from seating to back lie

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90
TOTAL	17	18	20	22	24	25	26	27	29	30
control	17	19	20	22	23	25	27	27	29	30
experimental	17	17	21	22	24	25	26	28	29	30

Table 9. Hanging on a lever with folded arms.

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	3.78	5.46	9.24	11.2	13.8	17.83	22.01	27.52	34.12	48.14	60.48
control	4.48	5.42	9.64	11.5	13.8	17.83	22.18	27.62	34.23	48.24	59.96
experimental	3.48	4.96	8.24	11	13.8	17.83	21.79	27.49	34.02	48.05	60.78

Table 10 Multi–stage shuttle test

GROUP	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
TOTAL	2.64	3.39	4.37	5.19	5.75	6.49	7.05	7.68	8.46	9.58	10.26
control	2.6	3.36	4.38	5.16	5.79	6.51	7.15	7.72	8.51	9.62	10.31
experimental	2.67	3.41	4.37	5.22	5.7	6.46	7.05	7.67	8.42	9.538	10.22

The goals we pursued with this kind of experiment are two:

1. to ensure the statistical indistinguishability between the control and experimental groups and

2. to build a normative base for evaluation of the pedagogical experiment

The first goal is obviously achieved in all the studied characteristics of motor skills.

The normative base in such cases is usually built with the help of variation analysis through the laws that control the normal distribution. However, our experimental results, as it turned out, do not have a normal distribution. That is why we chose to construct a six–point scale using the established percentile ranks. The grades are – poor (up to P20), fair (up to P40), good (up to P60), very good (up to P 80) and excellent (above P80). This scale can obviously undergo a number of refinements and improvements depending on the specific objectives of each study, the sensitivity can change at different intervals, but for the needs of the pedagogical experiment it turned out to be a reliable enough benchmark for comparative analysis.

The total integrated score on the six–point system for the experimental group after the experiment is 5.33 points, and for the control 4.93 points. The distribution of tests is as follows (Fig. 13):

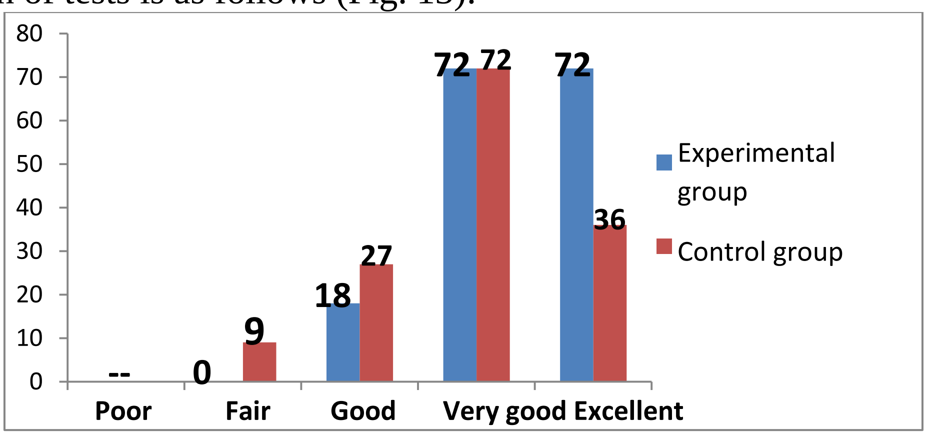


Fig. 13 *The general integrated assessment*

Although the methodology used is not directly aimed at the development of the studied motor qualities, it is obvious that it manages to influence them in a positive direction through the coordination structure. In other words, the obtained results with high statistical reliability confirm the raised working hypothesis.

It is noteworthy that in addition to achieving a higher score, there is a more significant homogenization of the experimental group – significantly lower values of the standard deviation and amplitudes in the variation series.

The data presented in this way represent a very integrated statistical assessment of the effectiveness of the methods used in the training process. Of interest is the detailed analysis of individual structures in the control system of the musculoskeletal system.

For example, in a number of sports, especially in martial arts, the speed of the motor reaction is essential for the final result. In laboratory conditions, the so–called simple and complex speed of reaction, which are largely determined by the conductivity and reactivity of neuromuscular processes. Another concept acquires the concept of motor reaction, which includes solving problems with more or less complex muscle synergy. In this case, the speed of the reaction will depend on the development of coordination abilities. We a priori do not expect our methodology to directly affect the motor qualities, including the speed of laboratory–determined simple and complex reactions, but it is quite logical that the reaction requiring complex intermuscular synergy to be a new quality of the control system.

Here we could distinguish reactions with varying degrees of complexity of the motor component depending on the number and nature of the muscle groups involved.

As the quantitative assessment of the speed of the motor reaction depends on a number of coincidences and uncontrollable conditions by the experimenter, it was necessary to determine in advance the number of necessary re–measurements to ensure the reliability of the assessment. The enclosed fig. 14presents the data from a similar experiment. A random number generator is used to vary the time interval between the transmitted light signals. In all subjects, stabilization of the mean value was observed at the latest after the seventh attempt.

Therefore, for the subsequent analysis, we adopted for individual evaluations the average values for the reaction rate obtained after ten experiments.

To assess the response with the participation of the coordination structure, we used a motor task for the fastest global movement of MGC

Using a video computer methodology and a dynamic platform, the time interval for the beginning of the motor action and the time interval for its overall implementation were determined.

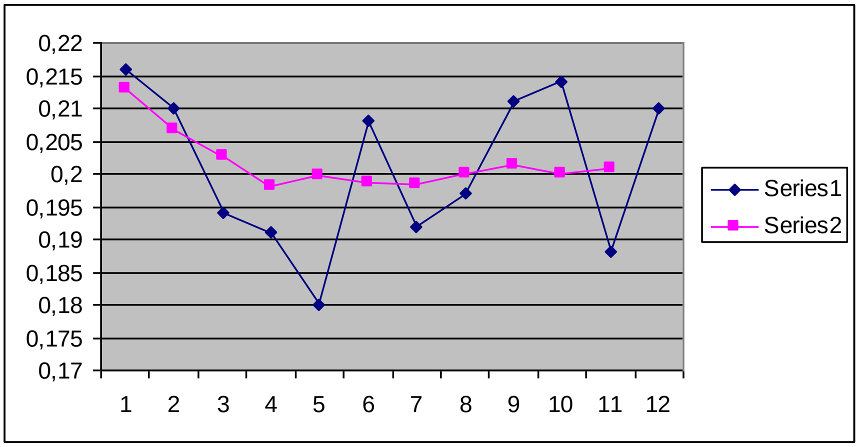


Fig. 14. *Quantitative assessment of motor reaction rate*

Table. 11 presents the results of the variation analysis of the two groups of subjects from the tests for simple and complex light stimulus response.

Table 11. Variation analysis of simple and complex reaction

Characteristic Group	**Δt1**	**S**	**V %**	**Δt1**	**S**	**V %**
Before the experiment						
Control	206	8	3.88	286	15	5.24
Experimental	209	9	4.30	291	16	5.49
After the experiment						
Control	208	8	3.84	284	14	4.92
Experimental	204	7	3.43	286	12	4.19

The exceptional stability of the displayed results and their objective independence from the training process is impressive. These types of reactions are largely genetically defined and their improvement requires targeted and innovative training methods. The latter is not included in the tasks of the present development, but in practice in the conditions of the specific sports and technical tasks, the motor reactions have their coordination dimension.

Table 12. Assessment of simple and complex motor response

Characteristic Group	Δt1	S	V %	Δt1	S	V %
Before the experiment						
Control	419	26	6.2	501	44	8.78
Experimental	422	28	6.63	497	48	9.65
After the experiment						
Control	422	27	6.39	499	38	7.61
Experimental	326	22	6.74	396	32	8.08

Table 12 presents data from experiments to assess prostate and complex motor response to global MGC displacement. Obviously, no statistically significant difference was observed between the two groups of subjects.

Of interest is the discovery of a possible relationship between the four tests performed – a standard simple and complex reaction of a light source and a simple and complex reaction in the global displacement of MGC.

Table 13. Results of the correlation analysis

No.	**1**	**2**	**3**	**4**	
1	1	0.72	0.46	0.49	control
2	0.71	1	0.45	0.41	
3	0.46	0.48	1	0.56	
4	0.51	0.44	0.51	1	
	experimental				

Table 13 presents the results of the performed correlation analysis of the control and experimental groups. The purpose of this comparative analysis is to find some hidden (masked) existing relationships.

The relatively low correlation between all parameters of the types of reactions before the experiment obviously demonstrates an objective difference between the evaluated characteristics and the relatively low realization efficiency of the motor potential.

The following table (14) presents the values of the correlation coefficients between the studied types of motor reactions after the experiment.

Table 14. Values of correlation coefficients

No.	**1**	**2**	**3**	**4**	
1	1	0.69	0.48	0.46	control
2	0.72	1	0.38	0.42	
3	0.78	0.81	1	0.48	
4	0.69	0.72	0.86	1	
	experimental				

The radical change in the structure of the experimental group is impressive. This result is directly related to the improved mechanism for realization efficiency of the available qualities of the control system of the own motor apparatus.

It can be assumed that, unlike ordinary simple and complex reactions, the nature of the sport develops in a specific way the speed of the motor reaction. in complex motor tasks.

The absence of the expected strong correlations between different tests for assessing the speed of reaction indicates the need to develop specific for the specific sport–specific motor tests for quantitative assessment.

The standard results for simple and complex response could be successfully used to determine the level of some countries of sports and technical mastery through biomechanical criteria for performance.

Another basic structure in the motion system is equilibrium stability. In many cases in the theory of sports science, equilibrium stability complements the five basic senses. For the purposes of our study, this feature is of particular importance due to its functionality and proximity to the auditory analyser.

It is known from the theory that there are three types of biomechanical criteria for assessing equilibrium stability – statistical; point and functional.

<u>Statistical criteria – Rs are:</u>

- √ Rs1 – percentage residence time of the projection of the MGC trajectory around the centre of oscillation
- √ Rs2 – percentage residence time of the projection of the MGC trajectory in the critical limit zone

√ Rs3 – angle of the trend relative to the optimum.

<u>The point criteria – Pt are:</u>

- ✓ Pt t– minimum distance to the contour of the support area.
- ✓ Ptv – maximum speed of the MGC projection to the contour of the reference area
- ✓ – + Pta – maximum speed gradient
- ✓ – + Pta1 – maximum acceleration gradient

<u>The functional criteria – Rf are:</u>

- ➢ Rft – dependence on the depth of the dependence of the state on the previous steps in the time sequence
- ➢ Rtf – criterion for resonant frequency

Targeted planned experiments to establish the causal relationships and individual features of equilibrium stability are likely to answer general theoretical problems related to the principles of control of the musculoskeletal system.

For the purposes of our study, we used the most integral criterion – Rs1 – percentage residence time of the projection of the MGC trajectory around the center of oscillation. The following figures show typical stabilograms from which Pc1 values were calculated.

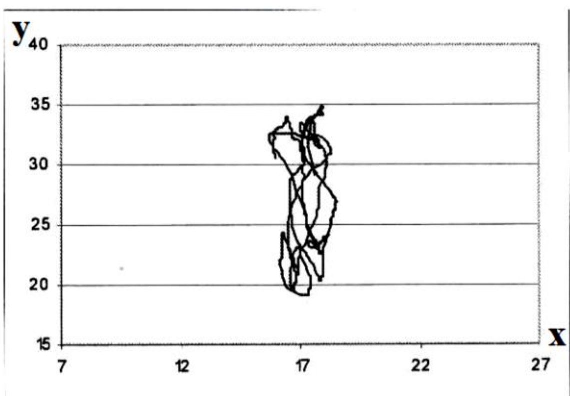


Fig. 15. *Projection of MGC at inclinations.*

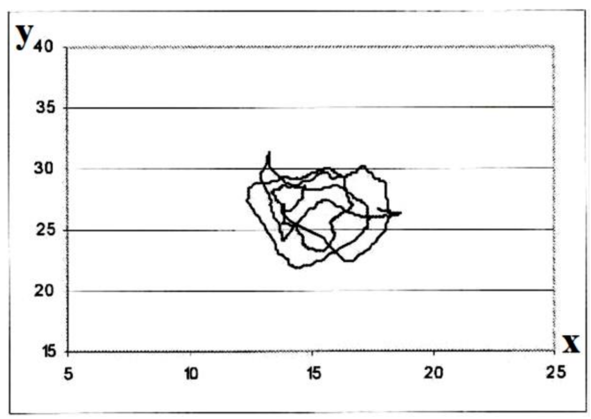


Fig. 16 *Projection of MGC in circles with head*

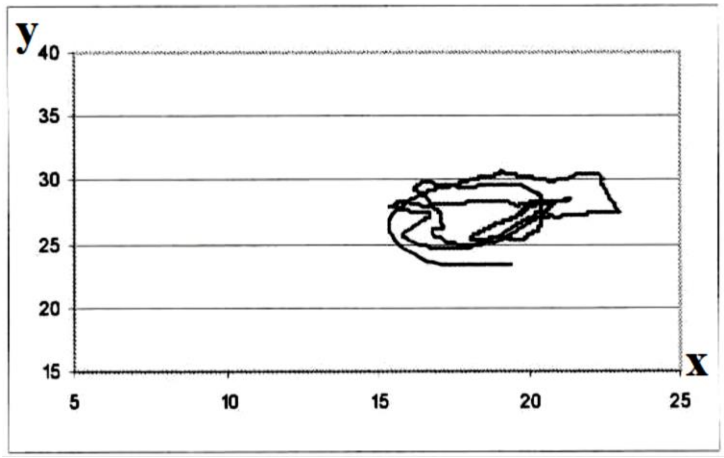


Fig. 17. *Projection of MGC in circles with the torso*

Table No.15 presents the results of the variation analysis for PC1 values.

Group	X1	S1	V1%	X2	S2	V2%	X3	S3	V3%
CG	98	21	21.43	121	31	25.62	136	36	26.47
EG	76	12	15.79	104	16	15.38	106	17	16.04

It is an obvious fact both in the improved management of equilibrium stability and in the homogeneous distribution of cases in EG.

Our initial experiments showed that regardless of the outwardly identical result (reduction of Rs1 values), in some cases the attention and analysis in the control cycle of MGC deviations are activated, and in others the mechanisms for "predicting the future" play a decisive role. Therefore, educational work should seek independent methods and means to improve these two types of mechanisms for controlling the musculoskeletal system.

The effectiveness of the experimental training methodology should ultimately affect the sports technical results. However, the latter, as is known from sports science, depend on too many uncontrollable factors. In addition, they carry the burden of a large percentage of random events. These facts compromise the idea that the evaluation of efficiency should be sought through the analysis of direct sports competitions between the two groups of experienced persons.

The most complete information about the nature of the changes in the experimental group is contained in the data from the conducted experiments for assessment of the main biomechanical characteristics during the implementation of a specific sports technical action. Fig. 18 shows the typical force function from the implementation of one of the main techniques in the fight – shoulder throw.

The character of the curve is preserved in all competitors, but with significant deviations in the coordination structure. The attempt to build a general model based on a statistical summary is illustrated in the following figure No. 19

It should be immediately noted that this type of mathematical formalism does not reflect objective truth. It can only carry information on some integral biomechanical characteristics, such as the average statistical impulse of force (area under the graph), operation, power, etc.

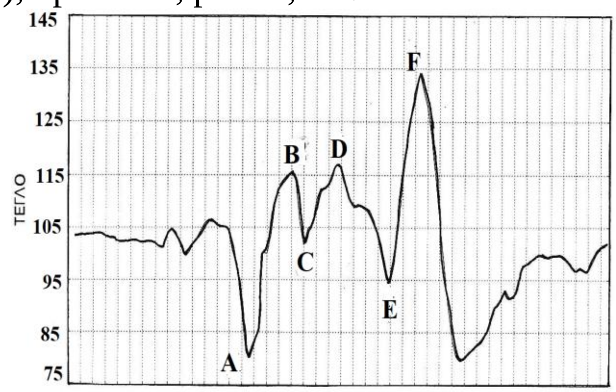


Fig. 18. *Shoulder throw force function.*

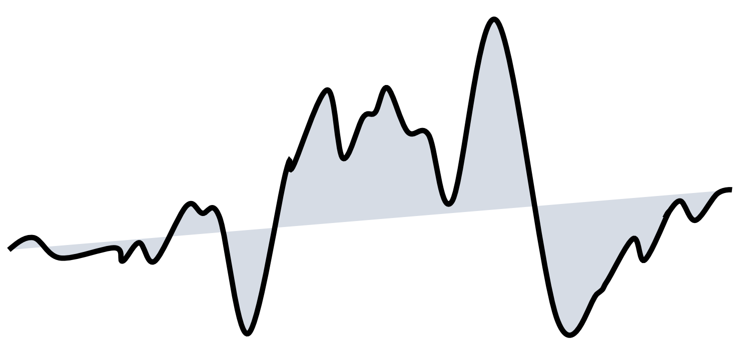


Fig. 19 *General model based on statistical summary*

In this statistical interpretation, the real causal relationship in the time sequence of the data for the force vector is lost. Virtually every actual value recorded is directly dependent on both the kinematic and dynamic history of the event.

In practice, the statistical model can in no way be a real phenomenon and should not be used as a model or coordinate evaluation system.

Another issue is the objectively registered point scores. For this purpose, we determined the special points on the registered analog curves. These are the global and more significant local extremes and inflection points. These points are indicated in fig. No. 19.

The statistical analysis of these specific values brings more meaningful information about the biomechanical expediency in solving the motor task.

The main disadvantage of this approach is the non–standard nature of the data, and hence the very high values of the standard deviations and respectively the coefficients of variation.

The rhythmic structure is invariant with respect to the absolute values of the force biomechanical characteristics and the weight categories.

The statistical model of the rhythmic structure for the "shoulder throw" technique is illustrated in fig. 20

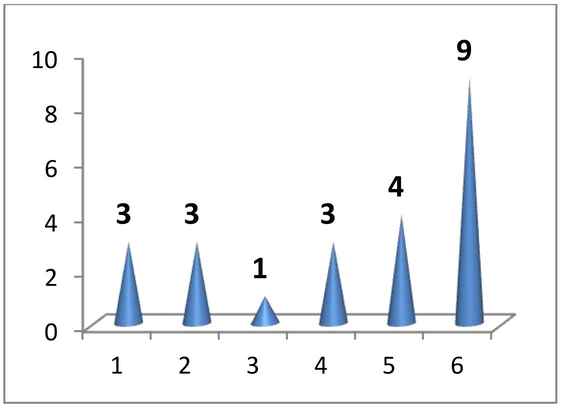


Fig. 20 *Rhythmic structure of "shoulder throw"*

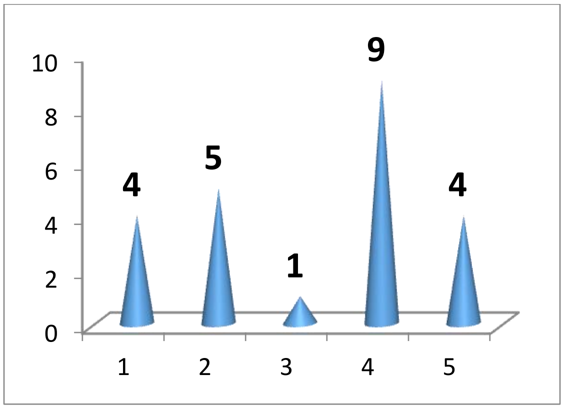


Fig. 21. *Rhythmic structure CG*

The comparative analysis between the control and experimental groups did not show significant differences in the rhythmic structure. This structure to a large extent forms the coordination abilities, but in the cases of automated actions in the learned motor habit, in the conditions of standardized external conditions it does not carry information about the latter.

That is why we performed experiments under variable initial conditions – height and weight of the partner and changes in posture and position but MGC, as well as performance in motion after the submission of an external light signal.

Changes in the initial conditions of the motor task led to significant disturbances in the rhythmic structure of the control group. These violations are in two directions – in terms of rhythmic coefficients and in terms of the homogeneity of the group. The results for the control group are illustrated in Fig.21

It is noteworthy that the rhythm disorders apply to all phases of motor action, while the force characteristics (max. force and momentum of the force) reduce their absolute values.

Fig. 22 presents the similar results from the experimental group.

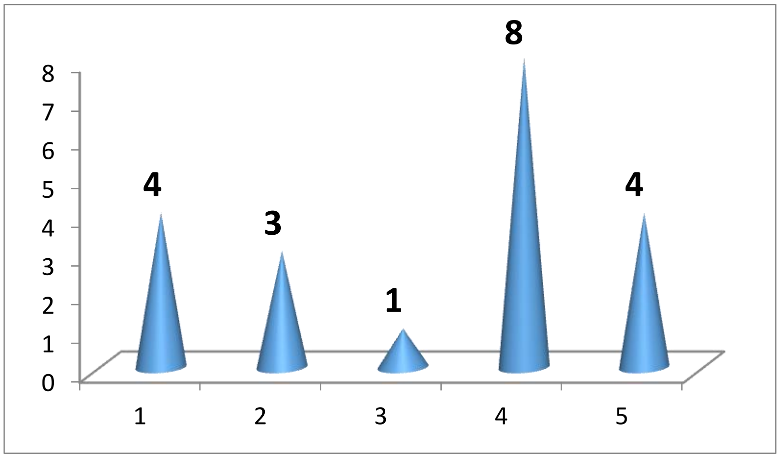


Fig. 22. *Rhythmic structure EG*

Here the changes are limited only for the first phase of the rhythmic structure, and in some cases the force biomechanical characteristics in the final phases increase their absolute values.

In our opinion, these results are of great interest as they reveal a new and sensitive indicator for the coordination abilities and respectively for the sports and technical mastery of the athletes.

For the purposes of the pedagogical experiment, we again used the test battery to assess the coordination capabilities, this time for the experimental and control groups of children with disabilities.

The indicators for determining the level of coordination abilities of an experimental group (EG) and respectively a control group (CG) of children with hearing impairment were studied, By all indicators, at the beginning of the experimental study, the control and experimental groups were homogeneous; the differences were not statistically significant.

To study the indices of coordination abilities, a test battery of 8 tests was used to assess the spatial, temporal and force parameters of the movements; spatial orientation; reaction speed; ; performing tasks in a given rhythm; vestibular stability; ability to speed the transformation of motor activity.

Change of the indicators for the coordination abilities from the conducted tests: Zig–zag, "T" test and Illinois before and after the experiment, respectively from the experimental group (EG) and control group (CG) are presented in Table 16

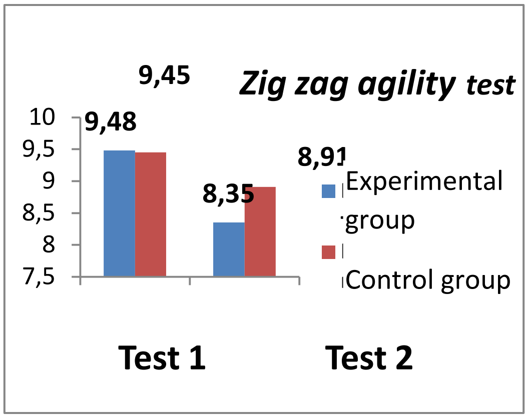
Table 16 Observed Zig–zag, T–test and Illinois agility test results

	Groups	**Zig-zag**		**T-test agility**		**Illinois**	
		Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
$\bar{X}$	EG	9.48	8.35	16.64	15.16	22.07	19.43
	CG	9.48	8.91	16.62	16.54	22.13	20.81
SD	EG	0.57	0.5	1.22	1.11	0.87	1.45
	CG	0.54	0.93	1.25	1.38	0.91	0.99
min	EG	8.16	7.76	14.73	13.2	20.87	17.06
	CG	8.94	7.88	15.86	14.29	21.5	19.62
max	EG	10.44	9.16	18.46	17.24	23.8	22.74
	CG	11.05	10.92	20.05	18.89	24.31	22.77
V%	EG	6.01	5.98	7.33	7.32	3.94	7.46
	CG	5.71	10.53	7.52	8.34	4.11	4.75

The purpose of the Zig–zag agility test is to monitor the development of the athlete's *speed*, *agility* and *spatial orientation*. The speed and agility of the legs and the spatial orientation are essential in the fight

There is no developed legal framework for evaluating the results of this test. The analysis of the test results was performed on the basis of their comparison with the results of the athlete from previous experimental data.

The changes in the indicators from the Zig–zag test are presented in Fig.23



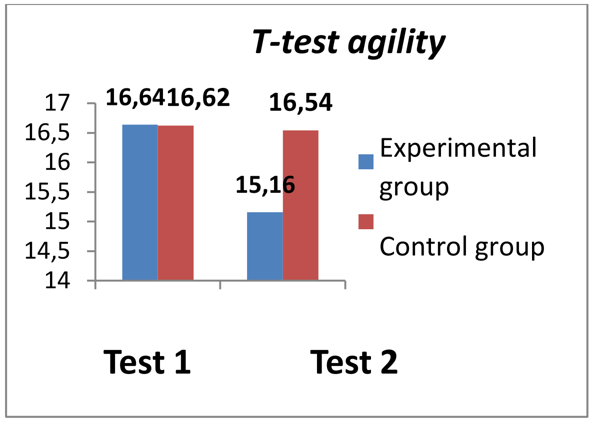


Fig. 23. Changes in *speed* and *spatial orientation* indicators

Fig. 24. *Changes in coherence ability indicators*

The T–Test agility assesses "a combination of leg speed, leg strength, performance dexterity and ability to coordinate"

Martial arts, and in particular wrestling, require skills such as a fast ability to process information and an adequate ability to react to rapidly changing information. This test examines the agility characteristic of the fighter (sequential choice reaction).

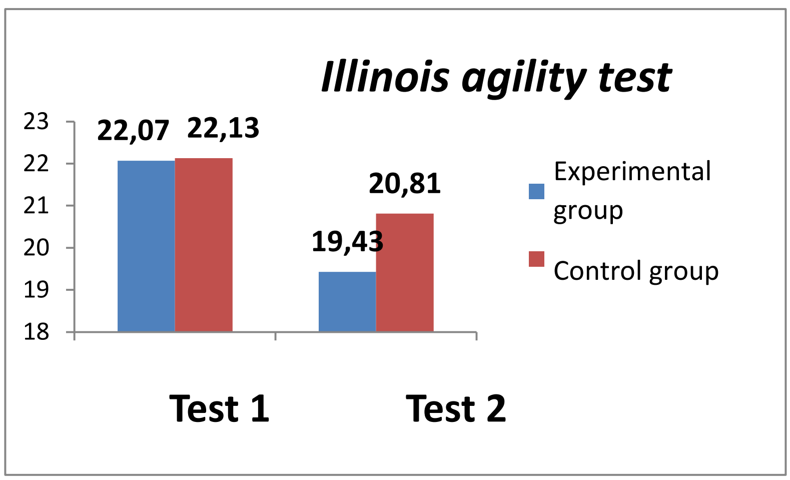


Fig. 25. *Changes in response capacity before and after the experiment*

The results of the statistical analysis show that the reaction time is significantly shorter in the experimental group than in the control group. In conclusion, the wrestlers in the experimental group had a better ability to react and better skills than the athletes in the control group.

Coordination is an important component of martial arts, although it is not always tested and it is often difficult to interpret the results. The Illinois agility Test (Getchell B. 1979) is a commonly used test for agility and *consistency of movement* in sports and as such has established norms.

In both groups, the test results are unsatisfactory according to Davis' regulatory framework (Davis B .; 2000). After the targeted improvement, the experimental group improved its results by an average of 30% more than the control.

The ability to quickly change direction and speed is essential in most team and individual sports. It is traditionally believed that this ability largely depends on the development of the explosive force.

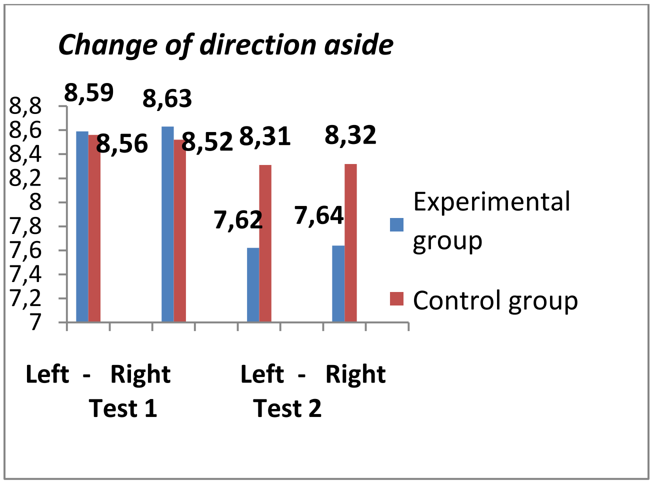
The results of the Reversal and Hexagonal agility tests before and after the experiment, by the experimental group (EG) and the control group (CG), respectively, are presented in Table 17.

Table 17. Observed test results Sideways change and Hexagonal agility test

#	Groups	Change of direction aside				Hexagon test agility					
		Test 1		Test 2		Test 1			Test 2		
		left	right	left	right	1	2	$\bar{X}$	1	2	$\bar{X}$
$\bar{X}$	EG	8.59	8.63	7.62	7.64	14.55	14.33	14.42	13.02	13.05	13.08
	CG	8.56	8.52	8.31	8.32	14.43	14.53	14.48	14.67	14.59	14.63
SD	EG	0.42	0.66	0.65	0.65	0.78	0.82	0.75	0.77	0.74	0.78
	CG	0.5	0.51	0.59	0.59	0.94	0.92	0.93	1.09	1.08	1.08
min	EG	7.4	7.73	6.34	6.32	13.23	13.23	13.45	11.89	11.73	11.79
	CG	8.22	8.2	7.3	7.15	14	13.9	13.95	13.03	12.92	12.98
max	EG	9.7	9.95	8.89	8.8	15.94	15.98	15.96	14.89	14.2	14.26
	CG	10.15	10.07	9.31	9.14	17.4	16.82	17.11	16.87	16.51	16.69
V%	EG	4.88	7.64	8.53	8.5	5.36	5.72	5.2	5.91	5.67	5.96
	CG	5.84	598	7.09	7.09	6,51	6,33	6,42	7.43	7.4	7.38

The ability to abruptly change direction or speed is essential in combat. It is a process that involves both perception and decision making as a result.

Tracking progress in the ability to quickly change direction and speed is presented in Table 17 and Fig.26



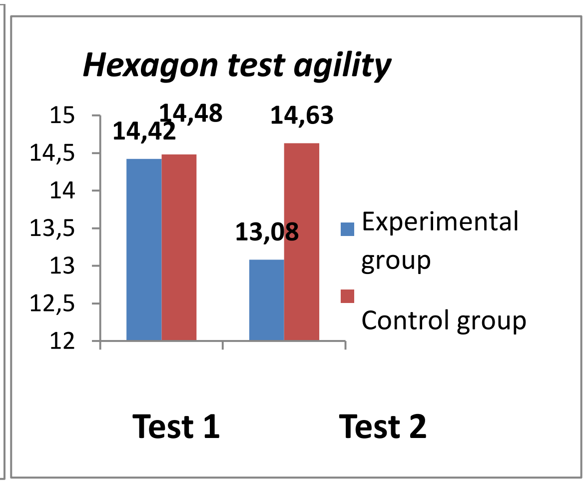


Fig.26 *Results from the development of the ability to change direction and speed.*

Fig.27 Change in the indicators for the rhythmic ability

We can reasonably say that the indicators of technical and tactical actions of the experimental persons from the experimental and control groups before the experiment are statistically different.

Change in rhythmic ability indicators in a hexagonal agility test is presented in fig. 27 and in table 17.

Standing Stork Test /Blind – SSTB test allows to assess the functional state of the vestibular apparatus and the level of static coordination.

To assess the dynamic balance, which includes the ability to control posture during movements and spatial orientation, we used the tests: Orb forward agility test (OFAT) and Step 50 agility test (S50AT) (Table 18).

The ability to balance (blind stork) after the end of the experiment in children from EG significantly exceeds the achievements in those from CG, which is proven by extremely high statistical reliability of the results.

Table 18. Observed test results Blind stork, Orb forward and 50 steps

#	Groups	Blind stork				Roll forward		Step 50	
		Test 1		Test 2		Test 1	Test 2	Test 1	Test 2
		Left	Right	Left	Right	$\overline{X}$	$\overline{X}$	#	#
$\overline{X}$	EG	4.09	5.19	8.68	8.83	15.15	14.51	119.94	69.66
	CG	4.04	5.39	6.25	6.28	15.19	16.31	121.37	122.37
SD	EG	1.72	2.06	2.88	2.83	0.53	1.48	52.39	42.7
	CG	1.24	1.41	1.64	1.77	1.22	1.22	60.31	39.99
min	EG	1.77	2.56	2.09	4.14	13.3	12.69	68	19
	CG	1	1	1	1	14.04	13.78	89	65
max	EG	4.84	10.77	13.14	16.52	18.53	17.76	245	162
	CG	4.6	5.17	6.47	6.9	18.28	17.56	208	201
V%	EG	42.05	39.69	33.17	32.04	10.12	10.2	43.68	61.29
	CG	30.69	26.15	26.24	28.18	7.48	7.5	49.69	32.67

There was no statistically significant difference in the ability to balance between the dominant and non–dominant leg.

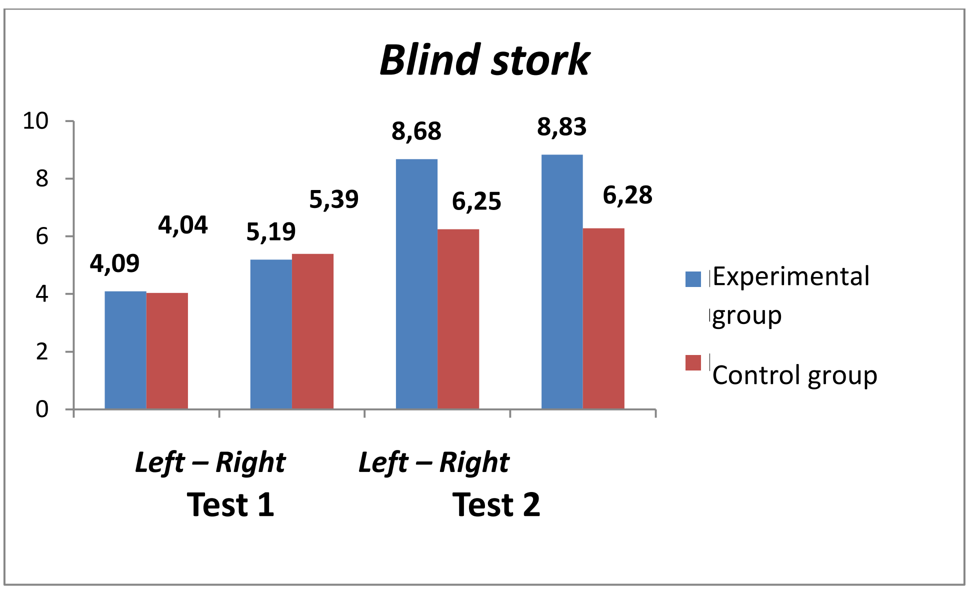
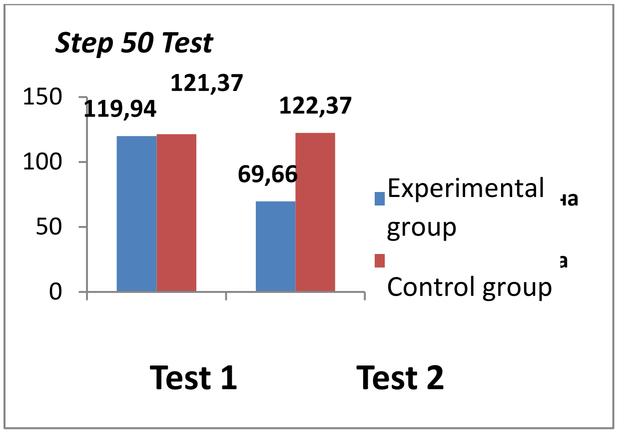


Fig. 28. *Change in balancing indicators*

The changes in the indicators of the ability for dynamic equilibrium after the end of the experiment to a large extent follow the logic in the development of static balance.



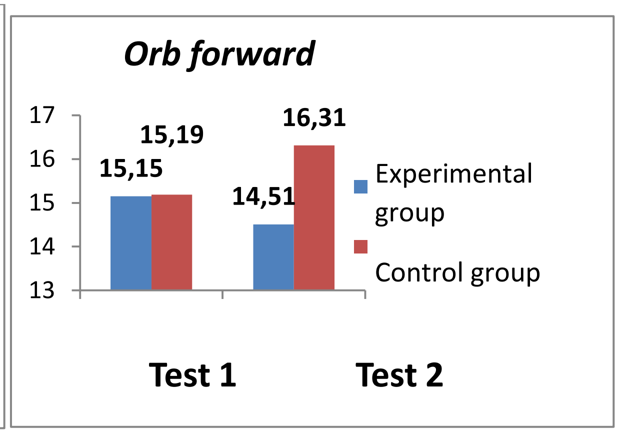


Fig. 30. *Change in indicators of vestibular stability*

Fig. 29. Change in vestibular stability parameters

Table 19. Normative based on the six–point system

Coordination abilities	Level assessment				
	poor	fair	good	Very good	excellent
Speed of reaction					
Change of direction aside	≥10,5s	9,5 - 10,4 s	8,5 - 9,4s	7,1 - 8,4s	≤7,1s
Equilibrium – static					
Blind stork test	0 - 4,9 s	5 - 6.6 s	6.7 -9s	9.1-10.9s	≥11s
Spatial orientation					
Zig zag agility test	≥10,8 s	10,7-9,8 s	9,7-8,6s	8,5-7,2s	≤7,1s
Ability to coordinate					
T-test agility	>19 s	17.5-18.9s	16-17.4s	14.3- 15.9s	≤14.2s
Rhythmic ability					
Hexagon test agility	> 17,8 s	15.6 - 17.8 s	13.4 - 15.5s	11.2 - 13.3 s	<11,2 s
Differentiation of motion parameters					
Illinois Agility Test	> 23 s	21.5– 22.9 s	20.5 – 21.4s	18.9 – 20.4 s	<18.8 s

For greater clarity and better motivating effect in children, we have prepared a standard based on the six–point system. The norm is in accordance with the experimentally established percentile ranks in the variation rows.

The obtained results are presented in the following table No.19

The behaviour of both groups on this normative base is illustrated in the following table. Here, the results illustrate much better the advantages of the methodology used.

The application of the proposed methodology in the training process significantly contributed to the development of the coordination capacity of the students from the experimental group.

Table 20. Assessment of the level of Coordination Capabilities

Coordination abilities	Level assessment				
	poor	fair	good	Very good	excellent
Speed of reaction					
Change of direction CG	0	2	8	3	3
Change of direction EG	0	0	6	8	4
Equilibrium – static					
Blind stork test CG	1	2	8	3	2
Blind stork test EG	0	0	7	7	4
Spatial orientation					
Zig zag agility test CG	1	2	7	4	2
Zig zag agility test EG	0	0	6	6	6
Ability to coordinate					
T-test agility CG	1	1	7	4	3
T-test agility EG	0	0	6	7	5
Rhythmic ability					
Hexagon test agility CG	1	2	8	4	1
Hexagon test agility EG	1	0	5	8	4
Differentiation of motion parameters					
Illinois Test CG	1	2	7	4	2
Illinois Test EG	0	1	7	6	4

Comparing the progress achieved during the study period by the control and experimental group, we found that students in the experimental group who use specific tools to develop coordination skills through targeted learning, have achieved better results in all areas aimed at achieving the objectives of the training program.

Based on the statistical and mathematical data processed and compared between the two methods applied in the experimental and control groups, respectively, we found that progress was more limited in the control group than in the experimental group for all tested parameters, so we can confidently say that the goal of our research work has been achieved and the working hypothesis raised after the theoretical analysis has been confirmed.

CONCLUSIONS

The following more significant conclusions could be drawn from the obtained results and their analysis.

1. The sensory system providing feedback in the control circuit of the motor apparatus is not a simple mechanical sum of the individual senses.

   The control system has significant compensatory mechanisms for objective assessment and control of motor action.

   For the needs of the training process such an integrating unit are the coordination abilities and their revealed two–way connection with the kinematic and dynamic structures.

2. The study of the mechanism of work for duplication of information by analysts is of interest not only for sports. The problem has a general theoretical significance for the health status, for the interactions between man and machine, for the adequate construction of training devices, etc.

   For the learning process of people with hearing impairments, targeted work to improve proprioceptive sensitivity is particularly effective.

3. The biomechanical analysis in laboratory conditions, of sports and technical actions under standardized external conditions, due to the built automation, does not bring information about the coordination

possibilities. The analysis becomes sensitive to the variability of the initial conditions.

4. Simple and complex reactions turn out to be stabilized structures in the locomotor system. Their eventual improvement needs a purposeful and long training process.

However, the motor reaction, realized in the conditions of an adequate motor task for the sports discipline, turns out to be a sensitive assessment of the coordination abilities of the athletes.

5. The statistical analysis with the help of generalized approximating functions does not carry information about real regularities in motor action control.

6. The rhythmic structure turns out to be invariant with respect to the absolute values of the force biomechanical characteristics and the weight categories.

This structure to a large extent forms the coordination abilities, but in the cases of automated actions in the learned motor habit, in the conditions of standardized external conditions it does not carry information about the latter.

This fact outlines a future opportunity for modeling sports technical mastery and defining the concept of biomechanical feasibility of motor actions in specific motor tasks.

7. The methods and means used so far in the training process are aimed primarily at improving the motor skills of the average statistical contingent of experienced individuals. This fact explains the violation of the normal law of distribution in the variation rows of the experimental data. A serious reserve for improving the training work is contained in the idea of more decisive individualization of training methods and tools.

RECOMMENDATIONS

The future development of the methodology requires the development of adequate training devices providing researcher–controlled variations in the external force field.

1. It is of general theoretical importance to continue the research to establish the causal relationships in the control circuit of the musculoskeletal system and in particular, the possibilities for interchangeability of the sensory systems providing the motor analyser. The complete solution of this task is in front of the united efforts of scientists from different scientific disciplines.
2. It is essential for sports science to develop a methodology for estimating the coefficients determining the depth of dependencies in the time order of the studied biomechanical characteristics.
3. The obtained results point to the possibility of modelling the sports technical mastery on the basis of the rhythmic structure and defining the concept of biomechanical expediency of the motor actions in specific motor tasks.
4. The methodologies used for training work are undergoing future development through the purposeful development of complex motor reactions.

On this basis, reliable and reliable tests for the realization efficiency of sports technical mastery could be developed.

PUBLICATIONS ON THE DISSERTATION

1. Dimitrova N., Nasiev Er., **Pavlov, Hr.;** "Quantitative assessment of physical fitness in primary school age" "Challenges and prospects for sports science", Scientific Conference of the Department of Weightlifting, Boxing, Fencing and Sports for All, 2 December 2, 2016, Sofia, pp.197-204, 2017, NSA PRESS, Sofia , *ISBN 978-954-718-492-3*
2. **Pavlov, Hr. (2018); "**What is the regularity in the time for preparation and realization of a competition in wrestling of NSA students from the coaching and teaching faculty"; Sports & Science; pp.103-109; Tip-Top Press; Sofia; ISSN 0324-136X 1310- 3393 (print)