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QUANTITATIVE ASSESSMENT AND NOMENCLATURE OF THE MENSTRUAL CYCLE PHASES IN ATHLETES: ANALYSIS OF CLASSIFICATIONS

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Abstract. The menstrual cycle can influence the well-being and physical performance of elite female athletes. Objective – to analyze existing approaches to the classification of menstrual cycle phases in female athletes in the scientific literature, with an emphasis on the quantitative definition and nomenclature of the phases used. The study was conducted in two stages. Methods of the first stage: the literature search was carried out in accordance with the PRISMA-S and PRESS checklists. The literature search was performed in the PubMed database. The time frame of the search was 5 years. No language barrier was set. Methods of the second stage: the ACCORD guideline was used to ensure compliance with reporting rules between experts. Participants were recruited through purposive sampling, during which a group of experts was selected based on the criteria of knowledge of the issue. The search identified 63 references. A total of 12 studies met the inclusion criteria. The studies indicated from 2 to 7 menstrual cycle phases with different names. The experts' opinions mainly differed in their commitment to consider the ovarian cycle (n=7, 50%), the uterine cycle of the menstrual cycle (n=5, 35%), and a mixed variant (n=2, 15%). The need for further research in the field of the menstrual cycle is due to the lack of unanimity among experts regarding the number of phases and their names. Until a consensus is reached in the scientific community, the results of all studies including female participants should be interpreted with caution.

Keywords: menstrual cycle, ovarian hormones, estrogens, progesterone, sports.

Introduction. Since Gamberale et al [1] showed in 1975 that pulmonary ventilation during submaximal exercise varies throughout the menstrual cycle, interest on an influence of female sex hormones on the performance of athletes picks up [2-5]. It is known that estrogen and progesterone fluctuations potentially influence the physical performance of women [2]. Maximal muscle strength appears to be higher in the follicular phase and in ovulation than in the luteal phase in both untrained [6] and trained women [7], while muscle fibre recovery and remodeling has been shown to occur faster in the mid-follicular phase than in the luteal phase following eccentric exercise [8]. Thus, there is a suggestion that estrogen fluctuations may influence the body's adaptive responses to physical activity [9]. For the same reason, the influence of the menstrual cycle on training response in female athletes has attracted particular attention [10, 11]. In their meta-analysis, Romero-Parra et al [12] have revealed that lower training activity or longer recovery periods may be observed in the early follicular phase, when sex hormone concentrations are lower and women may be more vulnerable to muscle injury, whereas strength training activity may be increased in the mid-luteal phase.

In the scientific literature, menstrual cycles are frequently divided into physiological phases from the simplest (two phases) to very detailed (seven phases) [13]. However, most previous studies tend to rely on a three-phase model with the assumption that there is a steady hormone level: menstruation (low sex hormones level, early follicular phase), pre-ovulation (high estrogen, late follicular phase) and luteal phase (high estrogen and progesterone) [14]. Despite its simplicity, the three-phase model does not take into account important hormonal shifts occurring during the cycle. It does not reflect the changes associated with the transition from high estrogen in the late follicular phase to ovulation, then to the luteal phase, characterized by high estrogen and progesterone, and finally return to menstruation. Hormonal changes during phase transition can be rapid and significant in magnitude, creating dramatic changes in a woman's hormonal environment and making homeostasis maintenance difficult [15]. It should be noted that the premenstrual phase, which is traditionally considered as a part of the luteal phase, is a critical period of dramatically reduced hormone levels and has hardly been studied in sports science research. However, it is in the premenstrual phase and during the subsequent

early follicular phase (menstruation) that unfavorable symptoms of the menstrual cycle are most common in athletes and increase the likelihood of the need for prolonged recovery from training [12], deterioration of the training process and performance [16]. Taking into consideration the analysis of the issue, data from modern literature and enquiries from sports biologists, physiologists and sports medicine physicians, we have formed the objective of the study.

Objective – to analyze existing approaches to the classification of menstrual cycle phases in female athletes in the scientific literature, with an emphasis on the quantitative definition and nomenclature of the phases used.

Methods and organization. The study took place in the Sports Medicine Department of the Russian University of Sport (Moscow). The ACCORD (ACcurate COnsensus Reporting Document) guideline [17] dedicated and applicable to all consensus methods used in biomedical studies was implemented to ensure compliance with the survey rules between the experts. The study included two stages.

Stage I. The researchers have conducted a systematic literature search in compliance with the ACCORD (items M6 and M7) guideline for the number and names of the menstrual cycle phases. The literature search was performed in accordance to the PRISMA-S [18] and PRESS (Peer Review of Electronic Search Strategies) [19] checklists. The following keywords were used in the PubMed database: (Menstrual Cycle Phase) AND (female athletes). The time frame of the search was 5 years. No language barrier was set and no study design restrictions were applied.

Stage II. Choosing the experts. Participants were recruited through purposive sampling, during which a group of experts was selected based on the criteria of knowledge, work experience, scientific interest and communication skills. The experts were recruited from the following areas: obstetrics and gynecology (n=4), sports physiology (n=4), coaching activity in sports (n=6, among which n=2 – biathlon; n=2 – rhythmic gymnastics; n=2 – weightlifting). The expert selection process started with sending an invitation via e-mail to the experts meeting the selection criteria by one of the authors (N.V. Lunina). The sent invitations had the following content: info about the research project, information consent forms and the literature review results on the number and naming of the menstrual cycle phases. The reviewers were invited to contact the author via email, phone or social media to discuss the sent project. In addition, the participants were invited to send info about the project to interested experts in the abovementioned fields of professional activity, who, in their opinion, are competent in the specified issue and meet the selection criteria. The interested experts then confirmed their participation via email. An approval from ethical committee was not required for the implementation of this study. All participants provided written informed consent prior to inclusion in the study. The ACCORD description provides info that there are no generally accepted standards for the number of experts recruited for the consensus. As a result, the committee target size (14 people) was determined by the desired representation and ensuring an acceptable response rate (7, assuming a 50% participation rate) in the event of non-participation or partial completion of the survey. The expert committee members who agreed to participate received an info package containing an introductory letter, a plain short summary, an informed consent statement as well as a questionnaire containing the literature review, the number and names of the menstrual cycle phases (table 1), against which the experts were asked to express their opinion in accordance with the presented data. If they disagreed with it, they were asked to present their option of the number and names of the menstrual cycle phases.

The interviewing process. The interviewing process included an online questionnaire that the experts completed over a 7-day period (January-February 2025). Participants were invited to rate their level of agreement with a number of statements assessing adherence to the number and names of the menstrual cycle phases.

Results and discussion. *Stage I results.* The search identified 63 references. Twelve studies met the inclusion criteria (table 1).

The studies indicated 2 [23, 27] to 7 phases with [13] different names. The smallest number of phases was identified by Homer et al. [23] – follicular phase and luteal phase, however Tagliapietra et al [27] used different names – early-follicular phase and mid-luteal phase. The greatest number was determined by Elliott-Sale et al [13]: early follicular phase, mid follicular phase, late follicular phase, ovulation, early luteal phase, mid luteal phase, late luteal phase.

Six studies have identified 3 phases. Romero-Parra et al [12], Thompson et al [20] and Guisado-Cuadrado et al [26] used the following names: early follicular phase, late follicular phase and midluteal phase. Tucker et al named them differently [24]: the follicular phase, the ovulatory phase and the luteal phase). Brown et al [25]: early-follicular phase, mid-late follicular phase and luteal phase. Galletti et al [28]: early follicular phase, ovulatory phase and mid-luteal phase. In the remaining 3 included studies, Bruinvels et al [14] identified 4 phases: late follicular phase, ovulation, luteal phase and menstruation, while D'Souza et al [21] named 6: early follicular phase, late follicular phase, ovulation, early luteal phase, midluteal phase, late luteal phase. Niering et al applied the same names [22].

Table 1

Literature review of the menstrual cycle phases in female athletes

Authors/year	Number of phases	Names of phases
Romero-Parra et al, 2021 [12]	3	Early follicular phase Late follicular phase Midluteal phase
Elliott-Sale et al, 2021[13]	7	Early follicular phase Mid follicular phase Late follicular phase Ovulation Early luteal phase Mid luteal phase Late luteal phase
Thompson et al, 2021 [20]	3	Early follicular phase Late follicular phase Midluteal phase
Bruinvels et al, 2022 [14]	4	Late follicular phase Ovulation Luteal phase Menstruation
D'Souza et al, 2023 [21]	6	Early follicular phase Late follicular phase Ovulation Early luteal phase Mid-luteal phase Late luteal phase
Niering et al, 2024 [22]	6	Early follicular phase Late follicular phase Ovulatory phase Early luteal phase Mid-luteal phase Late luteal phase
Homer et al, 2024 [23]	2	Follicular phase Luteal phase
Tucker et al, 2024 [24]	3	Follicular phase Ovulatory phase Luteal phase
Brown et al, 2024 [25]	3	Early-follicular phase Mid-late follicular phase Luteal phase
Guisado-Cuadrado et al, 2024 [26]	3	Early follicular phase Late follicular phase Midluteal phase
Tagliapietra et al, 2024 [27]	2	Early-follicular phase Mid-luteal phase
Galletti et al 2025 [28]	3	Early follicular phase Ovulatory phase Mid-luteal phase

Stage II results. Among 14 people invited to participate in the questionnaire, only 7 of them completed the Stage II (50%). 100% of the participants identified themselves as women. The most common answers are shown in table 2.

Table 2

Distribution of experts' answers by number and name of the menstrual cycle phases

Number of phases	2	3	7	4	6	3	3	4	4
Names of phases	FP LP	eFP lFP mLP	eFP mFP lFP O eLP mLP lLP	lPF O LP M	eFP lFP O eLP mLP lLP	DP O LP	eFP mlFP LP	Ml Fl Ol pLP	D R P S
Number of answers	-	-	1	-	-	6	-	2	5
Professional activity			1(OG)			2(OG) 2(cB) 2(cRG)		2(cW)	1(OG) 4(SP)

Note: FP – follicular phase; LP – luteal phase; O – ovulation; M – menstruation; D – desquamation; R – regeneration; P – proliferation; S – secretion. Periods (p) of the menstrual cycle phases: e – early phase; m – mid; l – late phase; p – post phase. Professional activity of the experts: OG – obstetrics and gynecology; SP – sports physiology; c – coach; B – biathlon; RG – rhythmic gymnastics; W – weightlifting. Cycles: – ovarian cycle; – uterine cycle; – mixed variant.

According to physiological data, during fertility, the menstrual cycle (MC) is regulated by a hierarchical complex interaction of all parts of the female reproductive system. The menstrual cycle regulation has a multilevel structure: 1st level of MC regulation – cerebral cortex and extrahypothalamic cerebral structures; 2nd level of MC regulation – hypophysiotropic zone of hypothalamus; 3rd level – anterior lobe of pituitary gland; 4th level – ovaries, where the ovarian cycle is divided into phases: follicular, ovulation, luteal; 5th level – target tissues (uterus, fallopian tubes, vagina, mammary glands, skin, bones, adipose tissue), where the uterine cycle is correlated with the phases: desquamation, regeneration, proliferation, secretion.

The differences in the experts' opinions are apparently associated with the peculiarities of the professional activity ensuring the emphasis on physiological processes occurring in different links of the reproductive system, conditioned by the level of regulation. The literature analysis covered the consideration of the ovarian cycle only. The experts' opinions mainly diverged on the adherence to consider the ovarian cycle (n=7, 50%), uterine cycle (n=5, 35%), mixed variant (n=2, 15%).

Conclusion. The menstrual cycle is an infradian (i.e. lasting more than one day), circamenial (i.e. lasting about a month) biological rhythm. During the menstrual cycle, there is a predictable periodic change in the concentration of the sex hormones produced by the ovaries – estrogen and progesterone. It is important to emphasize that there is considerable inter- and intra-individual variation in cycle length and hormone concentrations. In addition to their primary reproductive functions, estrogens and progesterone have been found to play a role in non-reproductive processes, affecting skeletal, cardiovascular and brain health. Thus, the menstrual cycle (more specifically estrogens and progesterone) has become a topic of interest to female athletes in terms of health and performance.

A significant part of studies in sports focuses on male population. Therefore, findings have often been incorrectly extrapolated to female athletes, leading to misconceptions about women's abilities and needs in sports. The reasons for this are, firstly, complex methodological issues faced by scientists in conducting such studies and, secondly, complexity of interpreting of various results frequently monitored in both separate studies and

when comparing different studies. Investigating the impact of the menstrual cycle phases on physical performance is an important component needed to develop women's evidence base in sport science. The development of this evidence base can improve understanding of how the phases can affect female athletes and inform how to design and implement training, recovery and monitoring programs for women with the phases in mind. A literature review and the expert survey revealed that researchers and experts identify between 2 and 7 phases with different names. Although identifying two phases is a useful tool, it does not adequately capture the diversity of hormonal changes characteristic of each. It is also common in menstrual cycle research to distinguish separate phases, each characterized by specific physiological changes. These phases include the early follicular phase, late follicular phase, ovulatory phase, early luteal phase, midluteal phase and late luteal phase. Therefore, further research is needed to obtain consensus among experts on the topic of the number and names of the phases. Until there is a consensus among experts, all studies involving women should be interpreted with caution.

Conflict of interest. The authors declare no conflict of interest.

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ANALYSIS OF THE FUNCTIONAL STATE OF ATHLETES AND NON-ATHLETES BY MACHINE LEARNING METHODS

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Abstract. The aim of the study – a comparative analysis of the functional state of athletes and non-athletes using machine learning methods. The input factors were experimental data on the physiological parameters and characteristics of the subjects obtained at the research center of the Volga Region State University of Physical Culture, Sport and Tourism. The selection of significant factors was carried out using the principal component analysis method. A detailed analysis of the experimental data was performed using artificial neural network and random forest models, for which optimal configurations and hyperparameter values were found. It was found that both methods allow identifying athletes and non-athletes by their physiological parameters and characteristics with a high degree of probability (over 90%).
Keywords: principal component analysis, artificial neural network, random forest method, functional state.

Introduction. In a modern world data mining methods come into broader use in different fields of human activity. For example, machine learning methods allow processing and analyzing vast volumes of data, find regulations and construct predictions, sometimes impossible for a human. In addition, artificial intelligence systems possess such important properties as self-learning and making autonomous decisions based on data without any obvious human assistance or program task. Currently, one of the most widely used applications of artificial intelligence is its implementation in description, prediction, classification and interpretation of complex data sets. In particular, such methods are used in medicine for diagnosis and analysis, as well as for making effective decisions [1]. In sports, this technology changes analytics, suggesting more detailed and precise understanding of each aspect of sports results [2]. Machine learning allows conducting a comprehensive analysis exceeding the possibilities of traditional methods.

The aim of the study is a comparative analysis a comparative analysis of the functional state of athletes and non-athletes using machine learning methods.

Methods and organization. To discover peculiarities of the functional state of different test subject groups (athletes and non-athletes), we used two supervised machine learning methods based on the experimental data: artificial neural network and random forest. The fully connected multilayer neural network consisted of four layers (input, two hidden ones and an output). An input layer included 11 neurons, where the parameters of the subjects characterizing the functional state and one noise parameter were taken as input. The first and second hidden layers included 32 and 64 neurons respectively. The brute force method identified hyperparameters that provide the model with the highest prediction accuracy and optimal values of weights. We also used the stochastic gradient descent [3] with splitting into minibatches of 10 training samples each and learning rate coefficient γ=0.001. Elementary thunks of this network that included input and hidden layer had a non-linear activation function ReLU (Rectified Linear Unit) while at the same time the output layer signal was transformed with the Softmax function. The root mean square error between the exact and predicted values was calculated to estimate the loss function at each iteration. The data set was divided into training and test sample in the ratio of 50/50%. The quality criterion – cross-entropy – was used to evaluate the model performance on the test sample.

As a second method of machine learning, we used the random forest method suggested by Leo Breiman and Adele Cutler [4]. The algorithm is used for classification, regression and clustering tasks. The main idea includes applying a multitude of decision trees, which combines the Breiman's "bagging" method and a random subspace method. In this study, we carried out learning of a number of random forest models

with a different number of trees. We have found that 10 trees are enough for a stable operation of the algorithm.

The experimental data included a data set consisting of physiological parameters and characteristics of tests subjects of both genders aged 10 to 27 years: age, maximal oxygen consumption (MOC), physical activity (hours/week), weight (kg), fat tissue mass (kg), muscle mass (kg), bone tissue mass (kg), protein, body mass index (BMI), body water (kg); parameters defining basal metabolism; one noise parameter, generated by a random number generator. The latter was used to test the stability of the predictive ability of machine learning methods. Two groups of subjects participated in the research: experimental (126 people or 82.89% of the total number of subjects) and control (26 people, 17.11%). The experimental group included athletes professionally engaged in certain sports (track-and-field, rhythmic gymnastics, badminton, tennis, soccer, volleyball, wrestling, martial arts, rowing, canoeing, swimming, etc.), as well as those who had sports titles and ranks. The control group consisted of young, healthy people engaged in moderate physical activity from 2 to 10 hours per week. All studies were conducted at the research centre of the Volga Region State University of Physical Culture, Sports and Tourism [5].

Results and discussion. At a beginner stage of the experimental analysis data analysis, we have calculated the Pearson correlation matrix between various parameters and characteristics of the subjects (fig. 1). It can be seen that a number of inherent physiological parameters have a strong correlation, such as physical activity and muscle tissue mass, body water and bone tissue mass etc. In order to reveal significant factors, we have performed the data dimensionality reduction with the principal component analysis method (fig. 2). Since all input parameters are described with different values and value ranges, we have performed a calibration procedure as a preliminary data processing in such way that the input parameter values were within the [0;1] range.

It is evident from the cumulative percent value of the explained variance (left column of the fig. 2) that four principal components explain 94.4% of the variance (at the recommended 60% variance). The first component explains 60.8% of the variance corresponding with 11 variables; the second – 22.9%; the third – 6.0%; the fourth – 4.66%. The right column of the figure 2 shows distribution of the experimental data for athletes and non-athletes in the plane of the first two components. As we can see, this diagram has two clusters: cluster with a compact distribution of points at negative values of the first principal component that characterizes the data of the control group, while the cluster with a scattered distribution of points in the area of positive values of the first principal component characterizes the data of the experimental group.

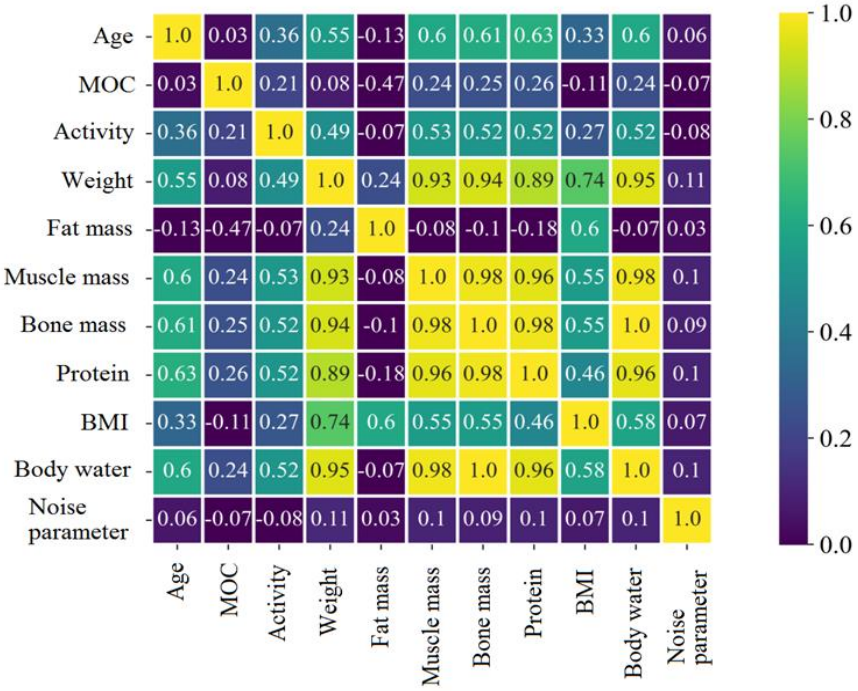

Fig. 1. The Pearson correlation matrix for the examined parameters

Taking into account the performed data preprocessing, we have built the artificial neural network model. The figure 3 demonstrated loss function (a) and model accuracy (b) as a function of iteration index. As can be seen from the figure, the model accuracy on the training sample was more than 93%.

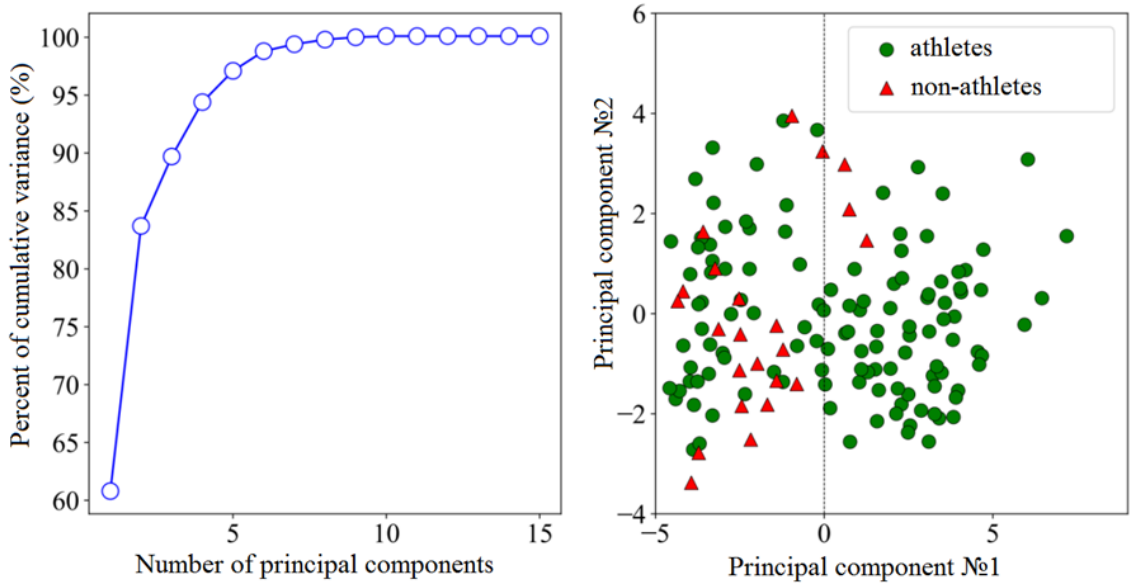

Fig. 2. The principal component analysis: cumulative dispersion percentage depending on a number of principal components (left column); data distribution in experimental (circles) and control (triangles) groups in the plane of the first two components (right column)

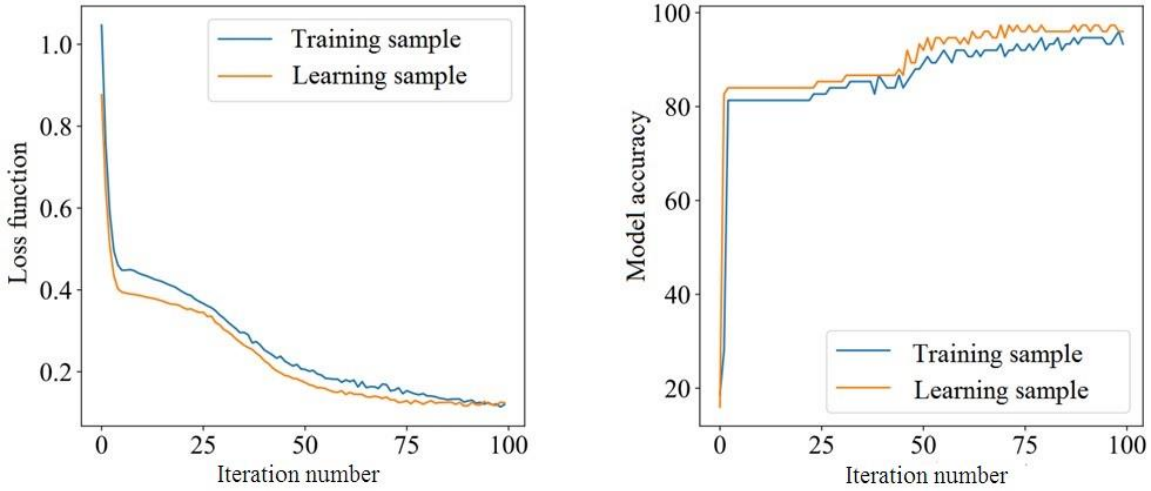

Fig. 3. Loss function (left column) and model accuracy (right column) as a function of iteration number

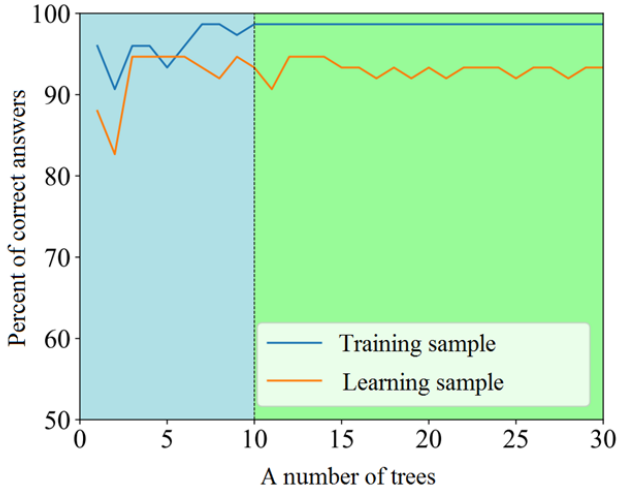

Fig. 4. Number of correct answers depending on a number of trees

The second stage of our study was an application of the random forest method (a multitude of decision trees used for classification and regression) in the experimental data analysis. We performed training of several random forest models with a different number of trees (fig. 4). As it seen from the figure, the percent of correct answers on the training sample reaches a plateau at value of 10 trees, which indicates stable operation of the algorithm at a minimum number of trees (N=10). Figure 5 shows a comparison of the predictive ability of two machine learning methods: the presented artificial neural network model and the random forest model with 10 trees. Both methods lead to the same results, namely, they allow to identify athletes and non-athletes by their physiological parameters and characteristics with high probability (over 90%).

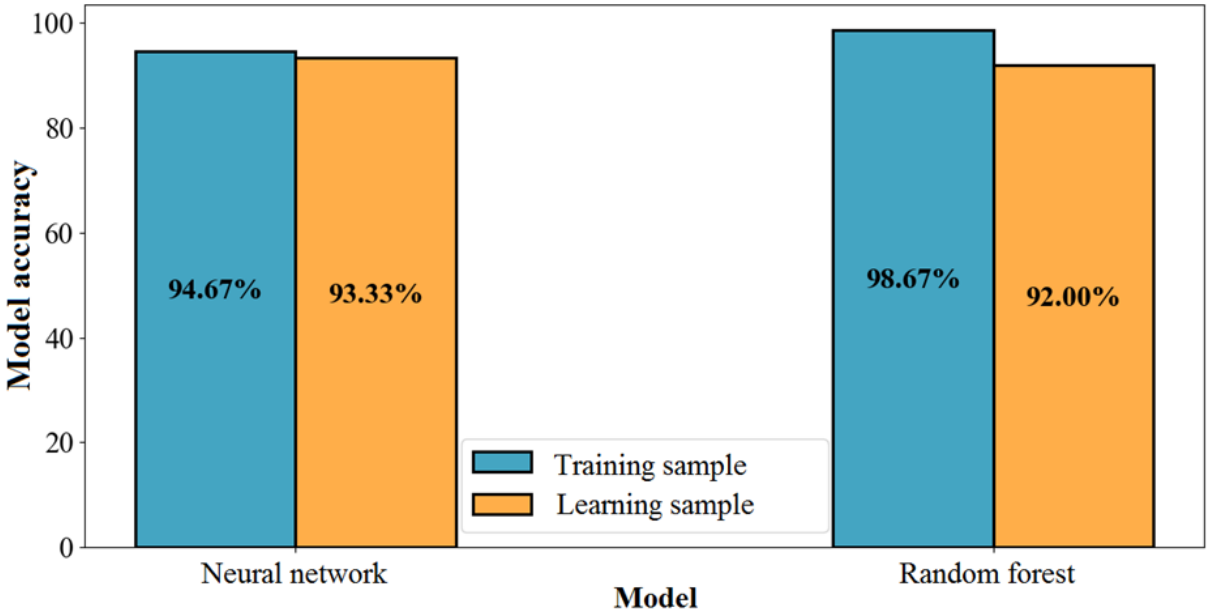

Fig. 5. Comparing the predictive ability of two machine learning methods: the artificial neural network model and the random forest model

Conclusion. We have conducted a systematic study of the functional state of athletes and non-athletes with two machine learning methods: the artificial neural network model and the random forest model. As input factors we used the experimental data on physiological parameters and characteristics of the test subjects. The significant factor selection was done with the principal component analysis method. We have wound that four principal components explain 94.4% of the variance (at the recommended 60% variance). For artificial neural network and random forest models, we have discovered optimal configurations and hyperparameter values. We have also found that both methods allow identifying athletes and non-athletes by their physiological parameters and characteristics with high probability (over 90%).

We have developed artificial neural network and random forest models, which allow defining the functional state of test subjects by a set of physiological parameters and identifying them as athletes and non-athletes (young, healthy people engaged in moderate physical activity).

Conflict of interest. The authors declare no conflict of interest.

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UDC 615.838

LANDSCAPE AND CLIMATIC POTENTIAL OF PYATIGORSK AS A FACTOR ENSURING EFFICIENCY OF SANATORIUM-RESORT TREATMENT, TOURISM AND RECREATION

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Abstract. The article is dedicated to a comprehensive study of landscape and climatic potential of Pyatigorsk using the example of microclimate indices of the S.M. Kirov Sanatorium, the Pyatigorsk Clinic and the Rodnik Sanatorium territory. Materials for the research included guiding documents, GOSTs, state reports, scientific papers and results of traversing. The conducted analysis has shown that values of the microclimate indices range within the standard. High level of light negative air ions and oxygen content, humidity, low level of carbon dioxide gas and aerosol particles in the air of the studied area have a favorable effect on a human body. A large amount of vegetation on the territories of sanatoria and the city as a whole provide great opportunities for efficient sanatorium-resort treatment, tourism and recreation.
Keywords: Pyatigorsk, climate, landscape and climatic potential, bioclimate, sanatorium-resort treatment, tourism, recreation.

Introduction. Pyatigorsk is a federal balneological and mud cure resort located in the Caucasian Mineral Waters, Stavropol Krai. One of the main unique recreational resources of this area is climate [1].

Climate of Pyatigorsk is moderately continental, without rapid temperature rises. Winter is mild and warm, and summer is hot and sunny with a smooth shift into dry and warm autumn. In Pyatigorsk sanatoriums, climate therapy (air therapy, terrain cure therapy, landscape therapy) comes into use thanks to such climate [2]. Healing air combined with therapeutic walking have a positive effect on general health improvement of the body [3].

Mountains and forest ensure a special microclimate suitable for recreation, therapy and health-improving physical culture at any time of year [4]. In addition, a great number of mineral water springs are located on the city's territory [5]. All of it attracts many tourists for sanatorium-resort treatment and recreation.

Study of the climatic potential of Pyatigorsk is relevant due to the preparation and issuance of special medical assessments in accordance with the requirements of the Russian Federation Government Decree № 681 dated 27.05.2024 "On preparation and issuance of special medical assessments". It also allows us to estimate the therapeutic and health-improving potential of the Caucasian Mineral Waters resort [6, 7].

Objective of the study – to identify the specific features of the landscape and climatic potential of the Pyatigorsk resort that ensure the effectiveness of sanatorium-resort treatment, tourism and recreation.

Methods and organization. Researchers of the Center of Biomedical Technologies (North-Caucasian Federal Research-Clinical Center of Federal Medical and Biological Agency) have conducted a study to identify the following microclimate parameters: air temperature, humidity and pressure, gamma-ray level of radiation pollution; aerosol particle (8 gradations in the range from 0.2 to 10 μm), oxygen and carbon dioxide content in the atmosphere (at the respiratory level of 1.5 m); positive and negative light air ion concentration on the S.M. Kirov Sanatorium, the Pyatigorsk Clinic and the Rodnik Sanatorium territories located in the Pyatigorsk resort zone, on the hillside of Mashuk.

The study materials included guiding documents, GOSTs, state reports, scientific papers and results of traversing.

The following devices were used: MAC-01 light-sized air ion counter, RadiaSkan-801 radiation dosimeter, SAChM 4801-01 aerosol analyzer (a mobile version), DT-1309 light meter, IKV-8 air quality monitor.

Table

Mean values of microclimate indices in the Pyatigorsk sanatoriums

№	Microclimate indices						
	T, °C	RH, %	AP, hPA	O_2, %	CO_2, ppm (number of units/million)	∑ [(N-)+(N+)] /IUC, background	O/T, Klux
S.M. Kirov Sanatorium	28.1	42.42	700.4	20.7	402.8	1318/0.84	23.76/7.34
Pyatigorsk Clinic	28.0	46.1	702.3	20.8	399.9	955/0.85	23.87/6.70
Rodnik Sanatorium	28.8	38.68	702.6	20.7	421.3	1074/0.76	23.99/10.4

Note: T, °C – air temperature; RH, % – relative humidity; AP, hPa – air pressure; O_2, % – relative oxygen content in the surface atmosphere; CO_2, ppm, number of units/million – relative carbon dioxide content in the surface atmosphere; ∑[(-) + (+)] / IUC (ion unipolarity coefficient) – air ionization background, ion/cm^3; O/T – luminance (Klux), in the open (O), and under the tree crown (T).

Results and discussion. Measurements of microclimate indices were done in different sports on each sanatorium's territory. The mean values are presented in a table below.

The geographic location of Pyatigorsk defines a variety of landscape types – from mountain ridges to steppe plains. Pyatigorsk is situated at the junction of several natural zones – the foothills of the Caucasus, the Stavropol Upland and the Kuma-Manych Depression.

Climate of Pyatigorsk is moderately continental, with hot, dry summer and mild, dry winter. Average temperature in July – +22-24°C (average temperature in July in 2024 exceeded the climatic standard, which is due to the research being conducted during the hottest months – July-August), in January – about -3-4°C.

Total precipitation –500-600 mm per year in average, with most of it falling in spring and summer.

One of the climate's features is high solar activity throughout the most part of the year, which makes Pyatigorsk attractive for resort recreation.

High air purity in the resort zone is described with low carbon dioxide content (399.9-421.3 units/million) in relation to the standard values (up to 450 units/million), high oxygen content (20.7-20.8%), the presence of volatile metabolites and high air ionization (955-1318).

The territory also possesses rich vegetation: common oak (Quércus róbur), common maple (Acer platanoides L.), common ash (Fráxinus excélsior), common lime (Tilia europaea), beech (Fagus sylvatica), hornbeam (Cárpinus bétulus), blue spruce (Pīcea pūngens), common spruce (Pícea ábies) etc.

Coniferous plants growing on the slope of Mashuk are noted for their high phytoncidal properties, which have a positive effect on the respiratory and nervous systems, and their ability to produce useful volatile organic compounds (VOCs), possessing therapeutic and health-improving properties that contribute to maintaining a high level of purity of the air basin, its "freshness", increased bacteriostasis, formation of favorable conditions for the organization of climate therapy, landscape therapy, outdoor recreation.

The level of aerosol particles of the surface atmosphere in the size range from 0.2 to 10 μm is considered an equally important indicator of air purity. This index varied from 65825 to 90097 particles/l in Pyatigorsk (fig. 1).

The biologically significant aerosol level in the size range of particles from 0.5 to 1 μm exceeded the standard in the Pyatigorsk Clinic, where the main part of the territory is located along the busy roadway of the resort area. The lowest value of ultradisperse aerosol (2580 particles/l) was observed in the territory of the S.M. Kirov Sanatorium (fig. 2).

The radiation and ecological survey has shown that the ambient equivalent dose rate (ADER) power was within the normal range (0.5 μSv/h) in all the territories (0.096-0.142 μSv/h), indicating no radiation pollution in Pyatigorsk (fig. 3).

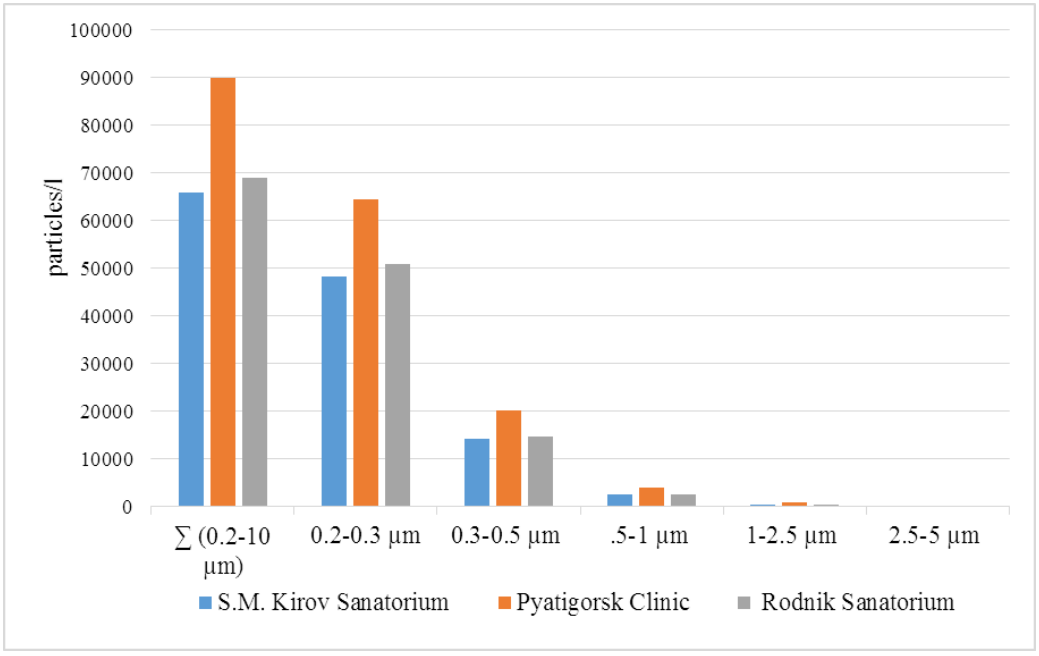

Fig. 1. Aerosol pollution in the Pyatigorsk sanatoriums

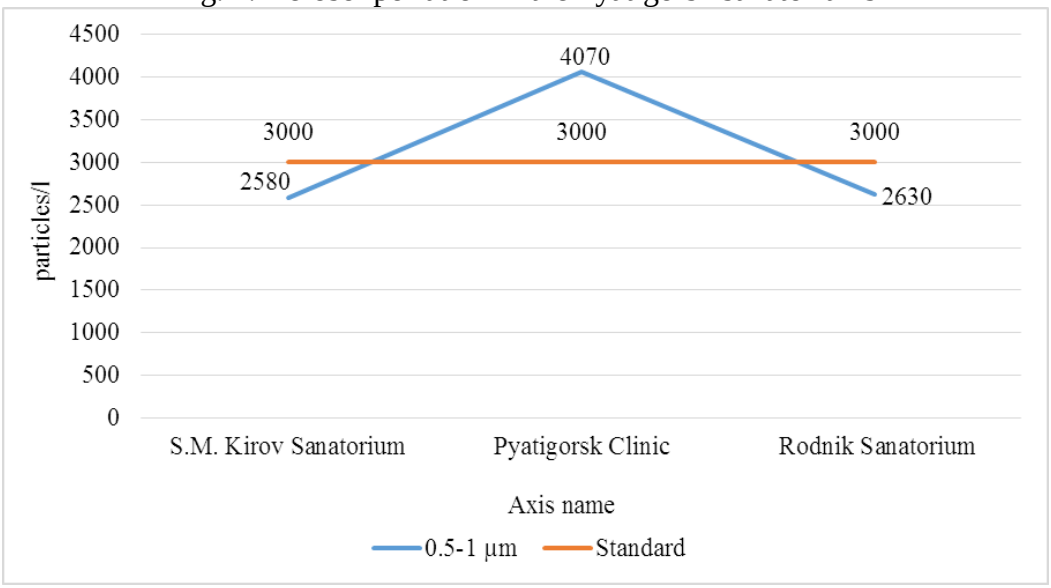

Fig. 2. Pollution of the surface atmosphere by aerosol particles (size range – from 0.5 to 1 µm) in the Pyatigorsk sanatoriums

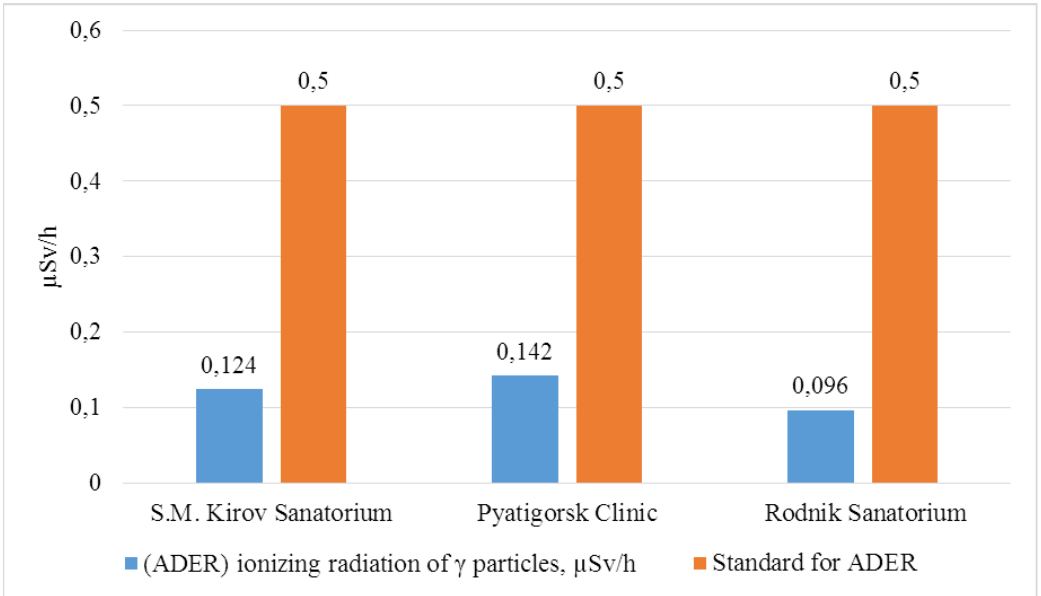

Fig. 3. Radiation pollution level in the Pyatigorsk sanatoriums

Conclusion. Landscape and recreational potential of the S.M. Kirov Sanatorium, the Pyatigorsk Clinic and the Rodnik Sanatorium territories is estimated as high according to the module technology accepted in balneology – 1.9 points (out of 3 possible) – and corresponds with the 1st rank.

Values of microclimate indices remain within the standard values and ensure favorable conditions for arranging heliotherapy, air therapy, climate therapy, terrain cure therapy and health-improving physical culture [8].

Patients undergoing sanatorium-resort treatment are recommended to walk on the territories of the sanatoriums and terrain cure routes located on Mashuk and in the resort area of Pyatigorsk.

The saturation of the surface atmosphere with oxygen and light negative air ions allows not only in summer, but also throughout the year to carry out recreating activities in the fresh air [8]. Physical activity provides improvement of metabolism and reduction of nervous system excitability, and staying outdoors accelerates metabolic processes in the body, strengthens blood vessels, improves heart function, excites brain activity, increasing the overall tone of the body [9].

Conflict of interest. The authors declare no conflict of interest.

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THE AEROBIC EXERCISE EFFECT ON THE FUNCTIONAL STATE OF ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS

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Abstract. Aerobic exercises are increasingly being included in the rehabilitation process to improve the functional state of the main body systems. Objective: to evaluate the effect of aerobic training on the functional capabilities of adolescents with idiopathic scoliosis. Methods: 6-minute walking test with an assessment of physical activity on the Baseline Dyspnea Index scale; spirometry; heart rate; determination of resistance to hypoxia. The indicators of external respiration (9.1%), general endurance (16.1%) and adaptive reserves of the body (3.2%) of adolescents improved. the improvement of functional capabilities was achieved with moderate physical exertion and a lower respiratory rate (16.4 breaths/min). Aerobic exercise increases the adaptive capabilities of the body and improves the functional performance of children suffering from musculoskeletal system pathologies.
Keywords: idiopathic scoliosis, correction, functional disorders, aerobic exercise, spinal stabilization.

Introduction. Idiopathic scoliosis is a three-dimensional spinal deformity defined by the presence of an arc of curvature with vertebral rotation, where the magnitude of the rotation angle reveals the degree of scoliosis [1, 2]. Scoliosis is a general term including a heterogeneous group of states consisting of changes in the shape and positions of the spine, thorax, and trunk. Despite the set of therapeutic and preventive measures taken, scoliotic deformity remains the most resistant to the effects of the applied methods of therapeutic correction.

The main goal of therapeutic treatment of scoliosis – to decrease the deformity ark and prevent its further progressing. The main tasks of correction treatment of scoliosis are considered an application of special exercises for spine mobilization and flexibility, of physical therapy measures aimed towards strengthening stabilizing muscles, paravertebral, abdominal, lower limb, and shoulder girdle muscles through isometric contractions in order to stabilize the scoliotic spine [1, 3, 4]. In case of idiopathic scoliosis, there are changes not only in the structures of the vertebral column, but also in the main systems of the body. Changes in the respiratory and cardiovascular system of the body are mostly associated with an increasing degree of spinal curvature [5, 6]. Main signs of such changes include dyspnea as a physiological response to standard physical activity, as well as sudden fatigue and an inability to perform standard daily work for long periods of time [2, 7]. The aforementioned signs can be noticed among adolescents with degree III and rarely degree II scoliosis, with a curvature of 20 to 45 degrees. These conditions may be caused by restricted ventilation and weak respiratory muscles. These limitations can be corrected through aerobic exercise. Special exercises included in the rehabilitation protocol can affect the physical performance and respiratory function of adolescents with idiopathic scoliosis, significantly improve the adaptive reserves of the cardiorespiratory system and the state of the musculoskeletal system [2, 4].

The aim of the study – to estimate influence of aerobic exercise on the functional capabilities of adolescents with idiopathic scoliosis.

Methods and organization. The study was carried out in the Yudino Therapeutic and Rehabilitation Center located in Moscow. The study period lasted 12 weeks. The observation group included 7 early adolescent children of both genders (according to the WHO classification), average age – 13.1±1.0 years. Taking the radiological findings into account, five adolescents were diagnosed with degree II and two with degree III scoliosis. According to the orthopedist's medical report, aerobic exercise was recommended for all adolescents. The criteria for inclusion in the study were: the presence of idiopathic II-III degree scoliosis

(Cobb angle – 21-34°), parental consent to include the adolescents in the observation group, and the absence of a history of cognitive and physical impairments that would prevent the performance of tests to assess the results.

The main methods of estimating the functional state of adolescents with idiopathic scoliosis are: 6-minute walking test (m) with physical activity assessment according to the BDI – Baseline Dyspnea Index scale (points); spirometry (vital capacity of the lungs – VC, l); HR – heart rate (beats/min); RR – respiratory rate (breaths/min); identifying hypoxia tolerance (breath-holding tests on inhale and exhale, s) [3, 5, 6].

At the beginning, aerobic activity included three 45-minute sessions per week for 4 weeks. Each training session started with a 10-minute warm-up, including low-intensity walking and stretching exercises. In the main part of the 20-25-minute session, children performed aerobic exercises on a treadmill (walking mode) and correction exercises. The load intensity was maintained within 60-70% of the maximum HR, according to the readings from the personal heart rate monitor. This operational control indicator was recorded on the training days before and after exercise. At the end of the study phase, the average HR for each adolescent and the group average were calculated. At the end of the session, all adolescents were offered a 10-minute period of rest and relaxation, including low-energy aerobic exercise such as slow walking and relaxation techniques performed in the supine position with the spine in a relaxed position. The stage control method (spirometry) was implemented to investigate the external respiratory function. Spirometry was performed in the sitting position with a commercial spirometer and a nasal clip. Forced VC was considered as a calculated indicator of spirometry. VC indices were recorded at the beginning and at the end of the study. Hypoxia tolerance testing was performed by measuring the inhalation and exhalation indices. The 6-minute walking test with physical load assessment on the BDI scale (from 0 to 12), where the total number of points can range from 0 (maximum dyspnea severity) to 12 (no dyspnea), was carried out to detect functional disorders of the respiratory organs during exercise. The following was recorded: total distance travelled in 6 minutes; HR; respiratory rate; dyspnea. In the final 4 weeks, the exercise time increased to 60 minutes, three times a week. The time of the main part of the session was increased by including special correction exercises. At the final stage, the repeated testing of the studied indices was carried out to compare the results obtained.

The results were analyzed by calculating the mean values (X) and the standard deviation (σ). The validity of the study results was processed with the Wilcoxon signed-rank test and the Student's t-test as long as $p \leq 0.05$.

Results and discussion. Changes in the cardiorespiratory system indices as a result are presented in table 1.

At the initial stage, the respiratory function tests helped to identify abnormalities, which were manifested by a decreased VC. By the end of the classes, improvements were noted in many aspects of respiratory function. There was a significant improvement (9.1%) in VC (table 1), as well as in breath-holding tests assessing hypoxia tolerance (table 2). The index of the breath-holding test on inhale increased by 10.5%, and that of the breath-holding test on exhale by 19.9%. As a result, hemodynamic changes of HR were also registered. The average index for the group improved by 2.2%, reflecting the adaptation of the cardiovascular system to exercise. Improvement of functional capacity in aerobic exercise was achieved at lower physical activity and lower respiratory rate (16.4 breaths/min). By the end of the rehabilitation course, a 5.3% decrease in HR was registered, reflecting the positive effect of aerobic exercise on the functional state of the cardiovascular and central nervous systems.

Changes in the respiratory function during physical exercise are presented in table 2.

The values of determining the functional state of adolescents with respiratory pathology and the therapy's effectiveness are shown in table 3.

The indices of the 6-minute walking test revealed significant improvement by 3.2%. The distance covered was achieved at a lower respiratory rate, indicating an increased tolerance to physical activity, as well as improved performance of the study participants.

The study of functional disorders on the part of respiratory organs during exercise are presented in table 4.

Table 1

Estimation of the functional state of the cardiovascular system of the adolescents during aerobic exercise, M±σ, n=7

Indices	Before the study	After the study	Difference in abs.units	Changes in %	P
HR, beats/min	78.6±2.6	76.9±2.0	1.7	2.2	≥0.05
RR, breaths/min	17.3±0.9	16.4±0.9	0.9	5.3	≥0.05
VC, l	2.0±0.2	2.2±0.2	0.2	9.1	≤0.05

Note: HR – heart rate; RR – respiration rate; VC – vital capacity of the lungs.

Table 2

Hypoxia tolerance study, M±σ, n=7

Indices	Before the study	After the study	Difference in abs.units	Changes in %	P≤
Breath-holding test on inhale, s	38.6±5.9	43.1±5.1	4.5	10.5	0.05
Breath-holding test on exhale, s	11.3±1.8	14.1±1.6	2.8	19.9	0.05

Table 3

Study of tolerance to physical activity, M±σ, n=7

Indices	Before the study	After the study	Difference in abs.units	Changes in %	P≤
6-minute walking test, m	496.1±12.0	512.0±11.1	15.9	3.2	0.05

Table 4

Study of dyspnea severity according to the modified Baseline Dyspnea Index scale after exercise, M±σ, n=7

Indices	Before the study	After the study	Difference in abs.units	Changes in %	Wilcoxon signed-rank test
Dyspnea, points	9.1±1.2	10.9±1.0	1.8	16.6	≤0.05

The respiratory act normalization is physiologically justified by more intensive lung ventilation achieved by increasing the volume of aerobic exercise. Consequently, positive (16.6%) changes in the dyspnea severity were noted, explaining the improvement of general endurance.

Conclusion. Combined aerobic training is able to improve external respiration (VC – by 9.1%) and hemodynamic parameters (HR – by 2.2%, RR – by 5.3%) of adolescents with idiopathic scoliosis. Improvement in functional capabilities was achieved with moderate exercise and lower respiratory rate (16.4 breaths/min). The assessment of the load quality and the adequacy of the cardiovascular system response during exercise was reflected in an increase in the external respiratory function indices (breath-holding test on inhale – by 10.5%, breath-holding test on exhale – by 19.9%). The use of aerobic exercise in complex rehabilitation can improve the indices of general endurance (by 16.6%), which determine adaptation to physical activity and functional efficiency (by 3.2%) of children with pathologies of the musculoskeletal system.

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HYDROKINESITHERAPY FOR CHRONIC LOW BACK PAIN IN BALLET DANCERS

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Abstract. Chronic pain in the lumbar spine is a manifestation of pathologies of the musculoskeletal system. For classical ballet dancers, this problem can become a serious obstacle, often leading to disability and, as a result, to the cessation of professional activities. Currently, there are many generally recognized rehabilitation methods, one of which is hydrokinesitherapy. Objective of the study: to evaluate the effectiveness of hydrokinesitherapy for chronic pain in the lumbar spine in ballet dancers. Methods: assessment of pain intensity and impaired vital activity; assessment of health-related quality of life; determination of functional mobility and flexibility in the lower spine. Hydrokinetic therapy reduced pain intensity (26.3%); improved physical (14.8%) and mental (11.3%) health of dancers; increased functional mobility (8.9%) and flexibility (7.4%) in the lumbar spine. Hydrokinesitherapy can be considered as an effective and safe therapy for patients with chronic pain in the lumbar spine. This approach helps to relieve pain, improve the quality of life and the functional capabilities of patients.
Keywords: hydrokinesitherapy, rehabilitation, physiotherapy, chronic pain, physical limitations.

Introduction. Injury of the spine with chronic pain is the most common and progressing disease of skeletal muscles [1-3]. Treatment of chronic back pain among people engaged in different types of physical activity continues to be the subject of active scientific study. Limited movement in the area, constant stress in muscles surrounding the spine and worsened motor reflexes characterize this disorder [2-4]. Studies show that pathologies of the lumbar spine are the fifth most common for representatives of choreography and dancing and account for 10 to 15% of the total number of traumatic injuries registered in ballet dancers [1, 3]. For ballet dancers, back pain sensations are commonly associated with high stress of the muscular and ligamentous system, which may lead to disability and, consequently, to end of professional career [5, 6]. Rehabilitation protocols of patients with chronic low back pain include advanced therapy methods aimed towards shortening the recovery period and accelerating return of patients to their professional activity.

Lately, physiotherapy has been increasingly used as an effective method of rehabilitation treatment. Physiotherapeutic approaches are of particular interest in the context of selecting ways, forms, and methods of rehabilitation in the comprehensive therapy of spinal injuries and pathologies. One of the methods of physio-therapeutic treatment of spinal pathologies is hydrokinesitherapy [7], based on therapeutic exercise in water. The key mechanism of its therapeutic effect is hydrostatic pressure of water, which relieves strain in the spine, joints and muscles of the patient. The influence of water properties helps to minimize pain and discomfort, relieve muscle tension, increase joint mobility and prevent recurrence of injuries in the future. All therapeutic and preventive techniques used in the rehabilitation of ballet dancers suffering from chronic low back pain have the main goal of prolonging their professional career [3, 4]. In this regard, the introduction of the most effective methods of low back pain therapy into the rehabilitation process of ballet dancers is a demanded direction and determines the relevance of our study.

Objective of the study: to evaluate the effectiveness of hydrokinesitherapy for chronic low back pain in ballet dancers.

Methods and organization. In our 8-week study, which included professional dancers of the "Classical Ballet Studio" located in Saint Petersburg, we have estimated the effectiveness of the applicable methods. The participants were divided into two groups: control (n=6) and experimental (n=7), average age – 19.1±2.0 years. The study involved the participants who met the following criteria: entries of chronic pain in the lumbar spine in medical history; professional activity in choreography; previous experience of using passive physiotherapy methods for therapeutic and preventive purposes.

The methods of ongoing monitoring included: assessment of health-related quality of

life (MOS SF-36 – Medical Outcomes Study-Short Form, points) – mental and physical health of the dancers was assessed; assessment of low back pain and impaired vital activity (points) – assessed with RDQ (Roland-Morris Disability Questionnaire), self-rated physical limitation caused by pain in the lumbar spine was registered [6]; determination of functional mobility in the lumbar spine (Schober test, cm); determination of flexibility in the lumbar spine (Hopkins test, cm). Comparative estimation of the results was carried out by calculating the mean values (X) and the standard deviation (σ). The reliability of the study results was processed with the Wilcoxon signed-rank test and the Student's t-test, as long as $p \leq 0.05$.

In the present study, participants of the experimental group underwent the rehabilitation course with hydrokinesitherapy. The therapy included sessions of exercises in water and therapeutic swimming held twice a week, lasting 50 minutes each. Therapeutic gymnastics (TG), including dry controlled spine traction therapy, was applied to the control group as a method of therapeutic and restorative influence. This method promoted decompression of intervertebral discs and relaxation of paravertebral muscles [5]. As part of the TG, controlled spine traction therapy with free weights were performed twice a week. The full course of rehabilitation therapy included 16 spine traction sessions.

Results and discussion. Table 1 shows the indices used to estimate physical and mental health of the dancers, as well as pain syndrome intensity influencing their activity during rehabilitation.

The analysis of quality of life indices in the ballet dancers revealed the advantage of hydrokinesitherapy over spine traction therapy. Thus, hydrokinesitherapy demonstrated a more pronounced positive effect on physical (14.8%) and mental (11.3%) health of the ballet dancers with chronic low back pain, in contrast to spine traction therapy (9% and 11.0%). In addition, a study of the pain syndrome degree showed a moderate reduction in pain (26.3%) at rest in the participants of the experimental group after the course, which is superior to the result obtained in the control group (18.9%).

The results of lumbar instability analysis in the observed groups are presented in table 2.

The study revealed a positive effect of the two applied techniques on the functional state of the lumbar spine in the subjects.

Table 1

Change in the quality of life aspects of the dancers during rehabilitation, X±σ

Indices/method	Experimental group (n=7)		Difference %	Control group (n=6)		Difference %	P
	Before	After		Before	After		
Quality of life - physical health - mental health (points)	57.9±3.4 69.5±6.6	68.0±3.0 78.4±6.0	14.8 11.3	60.6±5.9 69.9±5.0	66.6±4.5 78.6±4.5	9.0 11.0	≤0.05 ≤0.05
Pain and impaired vital activity (points)	3.8±0.8	2.8±0.5	26.3	3.7±0.6	3.0±0.6	18.9	-

Note: reliability of difference is presented with the Wilcoxon signed-rank test

Table 2

Changes in the functional indices of the dancers during rehabilitation, X±σ

Indices/method	Experimental group (n=7)		Difference %	Control group (n=6)		Difference %	P
	Before	After		Before	After		
Functional mobility, cm	13.2±1.0	14.5±1.0	8.9	12.9±1.6	13.9±1.4	7.1	≤0.05
Flexibility, cm	16.2±0.9	17.5±1.1	7.4	15.8±1.0	16.9±0.8	6.5	≤0.05

Note: reliability of difference is presented with the Student’s t-test

The indices significantly improved both in the experimental group (8.9% and 7.4%) and in the control group (7.1% and 6.5%). However, the hydrokinesitherapy method revealed an advantage over spine traction therapy, according to the data obtained. The results of the study indicate a favorable effect of hydrokinesitherapy on the lumbar instability, taking into account the professional activity of the subjects.

Conclusion. The final results of the study revealed that compared to exercises on land (TG), hydrokinesitherapy led to better changes determining the physical (14.8%) and psychological (11.3%) activity of the experimental group, reducing pain syndrome (26.3%) compared to the control group (18.9%). The investigated functional mobility and flexibility of the dancers in both groups demonstrated the effectiveness of the applied techniques, improving the indices in the hydrokinesitherapy group (8.9% and 7.4%) and (7.1% and 6.5%) in the spine traction group. Hydrokinesitherapy along with spine traction therapy may be considered as an effective and safe method of therapy for ballet dancers with chronic low back pain. This approach helps to reduce pain syndrome, improve the quality of life and functional capabilities of dancers. It is reasonable to use hydrokinesitherapy in rehabilitation programs for patients suffering from chronic low back pain in order to increase their motivation for further treatment.

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DYNAMICS OF KNEE JOINT FUNCTIONALITY AFTER ARTHROSCOPY IN THE RECOVERY PERIOD WITH THE USE OF PHYSICAL THERAPY MEANS

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Abstract. The article considers the dynamics of the knee joint functionality after arthroscopy in the recovery period using physical therapy means. The duration of the physical therapy course aimed at restoring the knee joint functionality after arthroscopy in the recovery period was 3 months. The following were used: therapeutic gymnastics, mechanotherapy, sessions with training devices, hydrokinesitherapy, massage, physiotherapy (cryotherapy, magnet therapy), proprioceptive gymnastics, kinesio taping of the knee joint. The total amount of rehabilitation sessions was 3-5 times a week with a duration of 60-90 minutes. The dynamics of the damaged knee joint functionality after arthroscopy is reflected in reliable improvements of the studied indices: the range of motion in the knee joint according to the goniometry data increased by 38.7% in flexion and by 126.2% in extension; the strength of the quadriceps femoris muscle of the thigh of the operated lower limb increased (according to the dynamometry data) by 77.2%; the functional state of the knee joint according to the Lysholm scale improved by 46.8%; the intensity of the pain syndrome according to the visual analogue scale decreased by 76.1%. The presented results reflect the positive changes in the knee joint functionality after arthroscopy in the recovery period with the use of physical therapy means.

Keywords: functionality, knee joint, meniscus, arthroscopy, physical therapy means.

Introduction. Tear of the knee joint's medial meniscus is one of the most common injuries of the musculoskeletal system among patients of young and middle age. According to the epidemiological data, medial meniscus tear incidence ranges from 12 to 14 cases per 100 000 population per year, with the highest peak incidence in the 18-30 age group [1].

In Russia, according to the Federal Register of Knee Injuries and Diseases, in 2022 more than 120 000 cases of meniscus tear, 70% of which were attributed to medial meniscus, were registered. The highest incidence is found among professional athletes and people leading an active lifestyle [2].

Along with the improvement of arthroscopic methods of meniscus tears treatment, the problem of the knee joint function restoration after arthroscopy remains relevant. In 30-40% of operated patients, signs of posttraumatic osteoarthritis develop in the long-term period, which leads to persistent limitation of physical activity and worsened quality of life [3]. The effectiveness of rehabilitation after arthroscopic meniscus surgery is largely determined by the quality and timeliness of rehabilitation treatment [4, 5], reflecting the relevance of the presented study.

Objective of the study: to estimate the dynamics of the knee joint functionality after arthroscopy among patients aged 18-25 years in the recovery period with the use of physical therapy means.

Methods and organization. The study involved 18-25-year-old patients (n=12) during the recovery period after arthroscopy with the "medial meniscus tear". There were 8 males and 4 females among the test subject, the average age – 21.5±2.4 years.

Inclusion criteria: age – 18 to 25 years; medial meniscus tear, confirmed by the MRI scan; prescription of injury – not longer than 3 months; condition after arthroscopy at 3-4 weeks; absence of other knee joint injuries (ligaments, cartilage); informed consent for participation in the study.

Exclusion criteria: age younger than 18 and older than 25 years; prescription of injury – more than 3 months; condition after arthroscopy at less than 3 and more than 4 weeks; presence of concomitant knee injuries; severe somatic diseases; refusal to participate in the study.

The knee joint functionality was estimated with the data from goniometry (º), dynamometry of the quadriceps femoris muscle of the operated lower limb (kg), the Lysholm scale

(points), the visual analogue scale (VAS, cm).

The statistical data processing was carried out with Statistica 13. The study's results were processed with the following statistical methods:

1) descriptive statistics (calculation of the arithmetic mean (X), standard deviation (σ));

2) checking the normality of distribution with the Shapiro-Wilk Test;

3) assessment of reliability of differences between dependent samples with the Wilcoxon signed-rank test.

The critical level of significance in testing statistical hypotheses was assumed to be 0.05.

Results and discussion. For improving the knee joint functionality of 18-25-year-old patients after arthroscopy, we applied the physical therapy (PT) means; the course lasted for 3 months. We used the following forms: therapeutic gymnastics (5 to 3 times a week for 15-60 minutes depending on a period), mechanotherapy on the Artromot, Kinetec devices, bicycle ergometer and elliptical trainer (5 to 3 times a week for 15-60 minutes), hydrokinesitherapy (3 times a week for 30-45 minutes), massage (every day to 3 times a week for 15-25 minutes), physiotherapy (cryotherapy 3-4 times a week for 10-15 minutes, magnet therapy every day for 10-15 minutes), proprioceptive gymnastics (3 times a week for 15-20 minutes), kinesio taping of the knee joint (applications once every 5 days). The total volume of rehabilitation sessions was 3-5 times a week, lasting 60-90 minutes.

Improvement of the knee joint functionality after arthroscopy in the recovery period is represented by reliable positive dynamics of the studied parameters (table).

Table

Changes in the knee joint functionality after arthroscopy in the recovery period with the use of physical therapy means, X±σ

Stage	Goniometry, º		Dynamometry, kg	Lysholm scale, points	Visual analogue scale, mm
	Flexion	Extension			
Initial	92.5±8.4	4.2±2.6	18.4±4.2	62.4±6.8	52.4±9.6
Final	128.3±6.2	9.5±1.4	32.6±3.8	91.6±4.5	12.5±5.1
P≤	0.05	0.05	0.05	0.05	0.05

At the initial stage of the study, the goniometry data revealed restriction of the knee joint amplitude of the operated limb: the flexion angle was 92.5±8.4º, which is 32.7% lower than the physiological standard (135-140°); the extension angle was 4.2±2.6° with the standard of 0-5° overextension. Such limitation of the knee joint mobility may be due to the persisting postoperative edema, pain syndrome and protective muscle spasm. At the final stage of the study, there was a significant improvement in the amplitude of the knee joint movement: the flexion angle increased by 38.7% to 128.3±6.2º, approaching the physiological standard.

Weakness of the thigh muscles, the quadriceps femoris muscle in particular, is a typical consequence of immobilization and reduced physical activity after injury and surgeries on the knee joint. Recovery of strength and endurance of the joint's stabilizing muscles is one of the key tasks of physical therapy, identifying its functional outcome. According to the dynamometry data, the values of the quadriceps femoris muscle strength amounted to 18.4±4.2 kg, which is significantly lower than the standard. At the final stage of the study, there was a significant increase in strength by 77.2%, up to 32.6±3.8 kg, approaching the age standard.

The Lysholm scale is implemented to assess the functional state of the knee joint, allowing quantitative characterization of the degree of impairment of its function, as well as the changes in knee joint recovery after injuries and surgeries. The Lysholm scale allows estimating the following parameters: limping, use of additional support when walking, pain, instability, edema, etc.

At the initial stage of the study, the Lysholm scale values of 62.4±6.8 points corresponded to the unsatisfactory functional state of the knee joint. At the final stage, the index changed by 46.8%, reaching 91.6±4.5 points, corresponding to a good functional state of the knee joint.

Pain syndrome is the leading clinical sign of medial meniscus tear and the main factor limiting

the patient's functional capabilities. Pain control and associated reflex disorders is one of the primary objectives of rehabilitation after arthroscopic meniscus surgeries. The initial level of pain syndrome according to the visual analogue scale was 52.4±9.6 mm, corresponding to moderate pain intensity. After the physical therapy course, the pain syndrome significantly decreased to 12.5±5.1 mm, corresponding to minimal pain sensations of the operated limb.

Conclusion. Significant improvements in the goniometry of the knee joint and dynamometry of the quadriceps femoris muscle of the operated limb, the functional state of the knee joint assessed by the Lysholm scale, the decrease in the pain syndrome intensity according to the visual analogue scale clearly reflect the positive changes of the knee joint functionality after arthroscopy in 18-25 year olds in the recovery period with the use of physical therapy means.

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OVERVIEW OF SCIENTIFIC RESEARCH ON PHYGITAL SPORTS

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Abstract. Objective of the study – to identify main directions of research on phygital sports and justify topics of prospective scientific works. The article provides a retrospective analysis of scientific articles on phygital sports on the eLibrary platform. 469 publications were studied, which allowed us to identify the main areas of research. Scientific research on phygital sports are of increasing significance in a context of rapid digital transformation of various fields of society, including sports. The greatest attention is paid to the integration of phygital sports into the educational environment, conceptual understanding of it as a phenomenon of digital transformation of sports, as well as comparison with esports. It has been revealed that the issues of sports training of phygital athletes and the effect of hybrid activity on the physiological parameters of phygital athletes have not been studied at the present time.
Keywords: phygital sports, phygital movement, sports, sports training, phygital.

Introduction. In the conditions of rapid digital transformation of all spheres of society, sport is not left aside from innovative solutions. One of the most promising sports are "phygital sports (functional and digital sports)" (hereinafter –phygital sports), which combine elements of classic (physical) sports and digital environments.

Phygital sports have been officially recognized in Russia since 2023 (Order of the Ministry of Sport of the Russian Federation № 58 dated 31.01.2023) and the format combining digital technologies and physical activity became actively supported by the state after the international multi-sport tournament "Games of the Future" and the emergence of the phygital movement (Order of the Government of the Russian Federation No. 3387-r of 24.11.2024). Its scientific study is necessary for the development of methodological foundations, optimization of training processes and analysis of various psychophysiological effects. Scientific research will ensure its effective implementation and Russia's competitiveness in the field of sports technology.

Holding the "Games of the Future" tournament, the basis of which included phygital sports, makes its scientific research relevant.

Objective of the study – to identify main directions of scientific study of phygital sports and justify topics of prospective scientific works.

Methods and organization. This study included a retrospective analysis of scientific articles on phygital sports (functional and digital sports) in the Elibrary database.

Results and discussion. During the study, a search by the keyword "phygital sports" resulted in 469 publication of different direction. The table below shows data on the availability of articles in the last 5 years.

Based on the data in the table it can be seen that the number of research papers has increased in 2023 and the 2024 of the international "Games of the Future" tournament.

Current research on phygital sports covers a wide range of topical areas, reflecting its interdisciplinary nature and rapid development. The analysis of published articles shows that researchers are most interested in the topic of integrating phygital sports into the student environment (22.8%). This indicates the high relevance of the introduction of phygital technologies into the higher education system, which is probably due to the active digitalization of educational processes and the involvement of young people in hybrid sports (fig.).

Considerable attention is also paid to the conceptualization of phygital sports as a phenomenon of digital transformation in sports (19.8%). This area includes research on the changes in the sports industry caused by the integration of digital technologies, as well as analyses of new formats of sports activities.

Table

Number of articles found in a search by the keyword “phygital sports”

№	Year of publication	Number of scientific papers
1	2021	-
2	2022	13
3	2023	121
4	2024	322
5	2025 (February 2025)	13

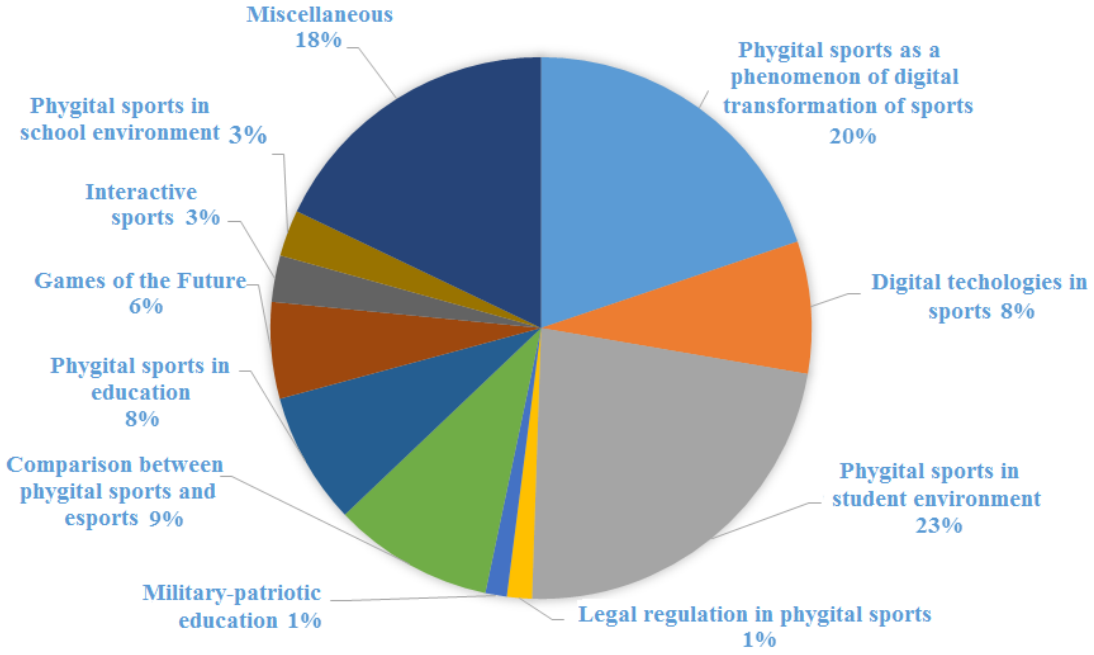

Fig. Research areas in phygital sports

One of the key issues remains the comparison between phygital sports and esports (9.4%), which confirms the existing debate on the boundaries between virtual and hybrid sport disciplines. The study of digital technologies in sports (7.9%) and issues related to educational aspects also play an important role in the research agenda. This emphasizes the tendency towards new pedagogical approaches in physical education based on the synergy between traditional and digital sports.

Less developed, but significant are the areas related to the legal regulation of phygital sports (1.5%) and military-patriotic education (1.3%). The lack of attention to these aspects may be due to the novelty of the phenomenon and the absence of an established regulatory framework, which makes these areas promising for further research.

In addition, there is a significant amount of research related to the “miscellaneous” category (17.9%), which indicates the presence of many specific and interdisciplinary works that require further systematization.

There are still unsolved and insufficiently studied issues related to sports training in phygital sports, taking into account the dual nature of their activity. Physiological features of phygital athletes also need to be studied in detail, as the simultaneous combination of physical activity and interaction with the digital environment can have a specific effect on the body, which is not yet studied.

The most cited are the directions encompassing general issues of phygital sports development and its main characteristics [1-5], phygital sports development in the student environment [6-10], comparison between phygital sports and esports [11], legal regulation [12, 13], digital technologies in phygital sports [14-17], management and commercializing in phygital sports [18], peculiarities in phygital sports disciplines [19, 20] etc.

Since Russia is the origin place of this sport, there are currently no foreign studies of it.

Conclusion. Scientific study of phygital sports are of increasing significance in the context of rapid digital transformation of all

spheres of society, including sports. They are necessary for the development of methodological foundations, optimization of the training process, as well for an analysis of psychophysiological effects, which, in its own turn, would ensure competitiveness of the state in sports technology. The scientific publication analysis has demonstrated a significant growth of interest towards phygital sports. However, some issues remain unsolved, such as legal regulation and sports training of phygital athletes (including study of physiological features of phygital athletes), reflecting a need in further study. These directions have prospects for more detailed scientific analysis and development of innovational approaches, which would ensure effective integration of phygital sports into sports industry and educational practice.

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PROBLEMS OF INTEGRALITY OF SPORTS TRAINING THEORY: BLOCK PERIODIZATION VERSUS TRADITIONAL SPORTS TRAINING THEORY

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Abstract. The main problem of this research was to find an answer to the question whether the theoretical assumptions related to the structure of sports training (principle relationship between microcycle, mesocycle and macrocycle) in traditional sports training theory are of a subjective/mechanical or objective/integral character. The aim of this research is to show the essence of the principle relationship between microcycle, mesocycle and macrocycle in sports training. Authors of the block periodization theory of sports training vigorously opposed the traditional sports training theory and pointed out that it has no objective scientific basis. Is that a justified claim that the timely integration of the effects of the microcycle, mesocycle and macrocycle of sports training explains the sporting form? The basic assumptions of traditional sports training theory are based on objective scientific knowledge of an integral character, and not on the subjective and mechanical division of the training process.
Keywords*:* load, adaptation, training effects, sporting form, macrocycle, periodization.

Introduction. There are several research programs considered within the knowledge expressed by leading theorists about sports training [1-9]. All "smaller research programs" have integrated into "larger research programs," which are denoted by the terms: traditional theory of sports training (TSTT) and block periodization theory of sports training (BPTST).

In the past 30 years, the problems of sports training theory have been increasingly discussed. The main characteristic of the discussion in the mentioned period is the beginning of the dialogue between Matveyev and Verkhoshansky on the periodization of sports training. Verkhoshansky began a dialogue with Matveyev with a fierce critique of the TSTT, and after that came Matveyev's response him [10, 11]. This dialogue was joined by other sports training theorists who defended Verkhoshansky [4, 12-14] or Matveyev [15-17]. The dialogue on current problems of periodization of sports training has continued, and in it the authors try to point out the strengths and weaknesses of the basic assumptions of rival theories [18-20].

The problem of interpreting the theory of sports training can be seen in the latest wave of dialogue on basic theoretical assumptions. BPTST starts from the assumption that the training process is founded on a "biological background" based on the theory of human adaptation, which includes the theories: homeostatic regulation, stress adaptation and supercompensation [21]. On the other hand, there is a thesis that shows that the interpretation of periodization based on "biological background" and "stress theory" (patterned application of mechanical load causes adaptation) is outdated and that a broader context of understanding training periodization should be approached. Based on the misinterpretation of the phenomenon of stress and the "recycling of old dogma", it was wrong to conclude that the periodization of sports training is based on old knowledge about stress [22].

It has been said and written that in TSTT, the training process is interpreted in a mechanical way, and that there is a subjective division of cycles, phases and periods. Verkhoshansky writes: Serious criticism by specialists practitioners refers to the essence of the concept of periodization of sports training – formal, mechanical fragmentation of the training process into subjective division of its parts (cycles, stages, periods) – that was the main idea and meaning of the concept of periodization of sports training [10]. In order to get a better interpretation and understanding of the problem, which is still relevant today, it is necessary to present the essence of the training structure in the macrocycle and essentially consider the objection made by Verkhoshansky.

The problem set by this research was to find an answer to the question whether the theoretical assumptions related to the structure of sports training (principle relation of microcycle, mesocycle and macrocycle) in the TSTT are of a subjective/

mechanical or objective/integral character. The main goal of this research is to present the essence of the principle relationship between the microcycle, mesocycle and macrocycle in the TSTT and to point out the correct interpretation of the basic theoretical assumptions.

Methods and organization. Analysis of domestic and foreign literature on the topic. A total of 29 sources were included.

Results and discussion. *Theoretical fundamentals of the macrocycle in sports training.* Every training cycle, regardless of whether it refers to a microcycle, mesocycle or macrocycle, has its own objective meaning and goal. The theoretical-methodological basis for the construction of the annual preparation is the theory of periodization, which was developed by L. P. Matveyev in his fundamental works, as well as authors such as Ozolin, Harre, Zhelyazkov, Martin, Carl and others [6]. Periodization of sports training deals with understanding the period of sports training, i.e. control of sporting form over time. Matveyev [23] was the first author to explain on a scientific level the basics of periodization of sports training and its principles, and thus set the foundation of the theory of sports training. The basic issue addressed by the periodization of sports training refers to the problem of organization and realization of training in time. In order for the training to be rationally organized and realized in the available time for preparation, with the goal of successful participation in the competition and achieving a positive sports result, the theory of periodization appeared, which divides time into periods. The aim of the periodization theory is to control the sporting form and achieve the best state of readiness and preparedness during the main competitions – achieving/demonstrating the best result [24]. Duration as a component of time is directly related to sporting form and says that sporting form lasts for a limited period of time [8, 24, 25]. The basic principle by which a sporting form can be explained, i.e., by which a sporting form is recognized, is the waves of the dynamics of its occurrence. Sporting form occurs in the form of large waves in the macrocycle. In large waves, three phases are regularly changed:

1) the phase of formation of a sporting form;

2) the phase of preserving relative stability of a sporting form;

3) the phase of temporary loss of a sporting form [8, 23, 26].

The phenomenon of changing the phases of sporting form occurs in cycles. The order of changing the phases of building a sporting form is always the same, and the number of cycles of a sporting form in one macrocycle defines the variant of periodization of sports training (monocycle, bi-cycle, tri-cycle, but there are other variants) [6, 23, 26]. The essence of the principled, phased occurrence of sporting form is not in the number of waves that occur in the macrocycle (the number of waves can be larger or smaller) but in the cyclical, principled change of the mentioned three phases which explain the dynamics of sporting form.

The main purpose of dividing the training process into periods is to acquire the conditions to build a wave of sporting form, i.e., the sporting form itself during the main competitions. Time units such as the preparation period, the competition period and the transition period are relatively independent, and at the same time inextricably linked. The essence of the division of training into periods lies in their easier integration into a whole. The greatest degree of integration is the integration of training and competition in the function of achieving results in the main competitions.

Within the period, there are stages in which the content of the training is defined. The preparation period is usually divided into the general preparation stage and the specific preparation stage. These stages of the preparation period are a precondition for the stage of integral preparation [26]. In the stages of the preparation period, through the application of exercises in training, the following are optimized:

1) the relationship of different types of preparation (physical, technical, tactical and psychological);

2) the relationship of volume and intensity;

3) the load in training.

All with the aim of acquiring conditions for the phase, which refers to the relative stabilization of sporting form.

A high degree of optimization is achieved by respecting the principles of sports training. The phase of relative stabilization of the sporting form coincides with the stage of integral preparation, i.e., with the whole competition period (if it lasts for a short time) or with the period of the most important competitions (if it lasts for a longer time). The content of the training, the optimization of the work from the aspect of the

specificity of the training process, largely determines the large wave in the macrocycle. In the macrocycle, integrality and specificity of the training process are controlled sporting form.

Theoretical fundamentals of microcycles and mesocycles in sports training. The microcycle is a complete work unit of training that can be different in duration, content and structure [26]. One of the basic characteristics of the microcycle refers to the processes of fatigue and recovery, as a result of the load on individual trainings [6, 9]. This process represents the relationship between fatigue and recovery in the microcycle that occurs as a consequence of the application of load during individual trainings. Fatigue and recovery are directly related to the size and direction of the load. Applying the appropriate load in a series of training in a microcycle can cause fatigue, recovery, as well as adaptation processes in the athlete's body. It should be remembered that the adaptation processes are directly related to the principles of sports training, which are based on biological and pedagogical principles [8, 27].

The principled change of the phase of fatigue and recovery during one-time loads causes short-term adaptation. On the other hand, by changing fatigue and recovery after a series of one-time loads, the process of long-term adaptation will gradually begin [6, 28]. Structural changes of adaptation can be achieved after a series of applied loads in which the continuity of the training process is not disturbed. Usually, microcycles last from 2-3 to 10 days, and in that short period of time it is not possible to achieve long-term adaptation in the athlete's body. It is possible to induce or complete of adaptation processes with a series of individual trainings. The goals of the microcycle can be different and depend on the stage or period of training in which they are conducted. The basic principle of microcycle control refers to the optimal application of load, in a short period of time, which has wavy dynamics. When optimizing the load in the microcycle, a distinction should be made between the stimulating phase (in which different variants of load dynamics can be applied) and the recovery phase (which can provide supercompensation after an individual training, as well as a small wave of training effects on previously applied load).

After the applied load in the individual training (whether it is a consequence of training of minimum targeted abilities or complex training), the process of supercompensation begins. Supercompensation is a biological principle that in sports training refers to the function of energy systems, and not to the optimization of work and rest or to the generalization of this phenomenon in the preparation of athletes [29].

The basis of short-term adaptation is the theory of supercompensation and the application of one-time loads, and the basis of long-term adaptation is the application of multiple loads and control of training effects. Depending on the period and stage of training, the main purpose of the microcycle is to optimize the load and various effects of training in order to achieve optimal preparation of athletes. The correct relationship between the stimulating phase and the recovery phase ensures the optimal load that occurs in the form of small waves in the microcycle. As a consequence of the application of loads in small waves, the characteristic of microcycles – a wave of training effects – occurs.

By linking a series of microcycles to the mesocycle, the load is controlled, which results in the cumulative effect of training. The load can be different in the microcycle, mesocycle and macrocycle, and is defined in relation to their characteristics and components. The main goal of mesocycle control is that the overall/cumulative effect of training, as a consequence of a series of applied loads in microcycles, is manifested during the main competition. Unlike the short-term effects of training in the microcycle, the cumulative training effect, as a consequence of the mesocycle, is a more permanent, more stable change. Therefore, the effect of training, in relation to the applied dynamics of load in the microcycle, will be different in different periods, as well as in the stages of training.

Integrating Microcycles, Mesocycles and Macrocycles of Training. The objective dynamics of each cycle in training is that the effects of the applied load occur in waves, and that the peak of the waves of positive effects of training can be in different periods of the macrocycle, depending on the set goal. Figure below shows the principle of the integration of structural elements of sports training in a monocycle variant of periodization, with the aim of achieving the best result in the main competition. This principle is of a generalizing character and can be applied to other variants of periodization of sports training.

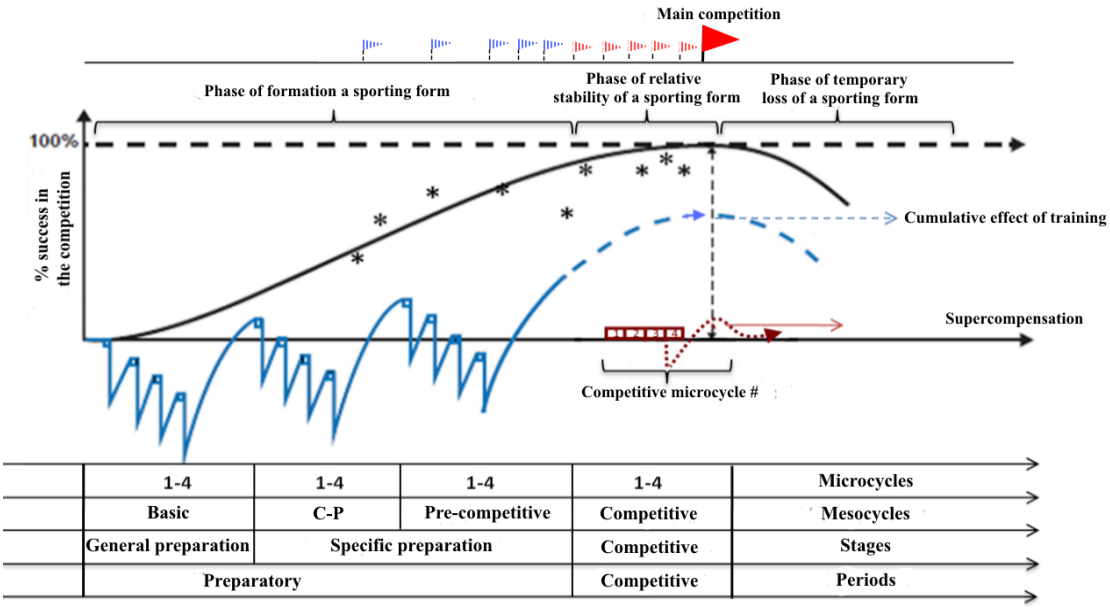

Fig. Integrating the structural elements of the training process in a monocycle variant of periodization
Note: * – result in competitions; C-P – control-preparatory microcycle. The competition microcycle is magnified to show more clearly on the chart. There can be more competitive microcycles in the competition period and stage.

A distinction should be made between the wave of the load dynamics in the microcycle, mesocycle and macrocycle and the training effects that result from the application of the load in the mentioned cycles. The smallest wave of training effects that can occur is supercompensation. This phenomenon explains the effect of individual training, i.e. the effects of the solved task or tasks on individual training by applying a one-time load. By summing several supercompensation effects, a wave of effects is achieved, which is a consequence of the dynamics of small load waves. This phenomenon is characteristic of the training microcycle. The first meaning of the microcycle lies in the integration of the peaks of the supercompensation wave with the wave of training effects as a consequence of the application of small load waves. The second meaning of the microcycle refers to the integration of the peak of the training effect wave in the microcycle with the peak of the training effect wave in the mesocycle.

The mesocycle of training connects the wave of training effects in the microcycle with the wave of training effects in the macrocycle. In the mesocycle, the wave of training effects is controlled, which has a cumulative character. The first meaning of the mesocycle lies in controlling the cumulative training effect. The second meaning is to integrate the peak of the cumulative effect of training with the peaks of the waves related to the dynamics of the effects of training in the microcycle, as well as individual training. The third meaning refers to the fact that the wave of training effects in the mesocycle is integrated with the wave of training effects in the macrocycle.

In the macrocycle lies control the large of waves that are characteristic of sporting form. The main characteristic of the big wave is load optimization and specificity control in physical, technical, tactical and psychological preparation. The essence of the control of specific work is the integration of different types of preparations, with the aim of achieving sporting form during the main competitions. First, the macrocycle integrates the effects of small and medium waves of training with the large wave of training effects, which in an integral sense represent a sporting form. The highest degree of integration of different types of preparations is achieved during the competition period by a series of competitions that precede the main competition (fig.). The result at the main competition is the basic criterion of sporting form. Secondly, it is necessary to integrate the sporting form with the period of the main competitions. With the absence of an integrated approach in sports training, the possibility of controlling the training process is practically lost.

The extent to which authors who talk about the mechanical planning of the microcycle and

mesocycle within the macrocycle are not right is best seen at the time of the most important competition (fig.). Then the effects of supercompensation of the last microcycle, the cumulative effects of pre-competition mesocycle training and the state of the athlete's sporting form must be integrated. Each of the three components must be prepared separately and integrated in a timely manner into a single unit in relation to the most important competition. If one of those three components is not at the required level at the same time – the time of the competition – the athlete cannot achieve his or her best result.

Final comment. It should be remembered that any mechanical management of sports training directly violates and crushes the principle of building a sporting form. Verkhoshansky's thesis that the meaning of TSTT is "mechanical fragmentation of the training process" absolutely does not correspond to the basic theoretical assumptions related to the building of the training process. Such a thesis probably arose as a need to quantify training. The value of the quantitative aspects of training is of great importance, there is no doubt about that. However, the full meaning of the training process is achieved when the training is supplemented with qualitative aspects, which means an integral, unified view of all aspects of the training process. The integrality of various aspects of sports training is not based on subjective-speculative principles such as: "it can be either this or that way," but on objective theoretical bases that have a principled character and that are practically applicable. In serious theoretical analyses that have been presented to the scientific community during the history of the development of the theory of sports training, nowhere is it written that training is partially mechanically built on the basis of a subjective division of cycles, stages and periods. The basic guideline of the whole research program, which refers to the TSTT and the Eastern European scientific school, refers to the integration of scientific knowledge in the function of achieving results in the main competitions. Without objective evidence, a critique of the TSTT has recently begun, which is being multiplied on the basis of unchecked and insufficiently strong scientific evidence.

Conclusion. There is an objective structure of sports training based on the principles of sports training. These principles do not have a fragmentary character but are interconnected and form an inseparable whole. The main purpose of studying the principles is the integration of different parts of sports training, and not arranging and stenciling its structural elements. The TSTT is scientifically based, it contains biological-pedagogical knowledge that is a consequence of many years of research work. As can be seen, the TSTT is not built on a template, mechanically or subjectively, as Verkhoshansky and his followers believe. The basic theoretical assumptions of TSTT testify to the integrality of the training process - integrating the aims of the microcycle, mesocycle and macrocycle with the aim of achieving results in the main competitions. The control of the sporting form and the training process depends on the degree of integration of the goals of the microcycle, mesocycle and macrocycle, and not on the subjective division or template arrangement of the structural elements of sports training.

In line with what has been said, it is still early to accept BPTST as a "new theory", a "new paradigm". It is necessary to consider more carefully the existing knowledge about sports training and to determine whether the new knowledge about sports training is incredible in the light of already existing knowledge, and then propose a new theory or theorem. Future theoretical knowledge should be supplemented by interpretations that tell what the similarities are, not just the differences between TSTT and BPTST.

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