



The model of prediction of changes in the functional state of athletes engaged in hand-to-hand combat under the influence of the training load

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Abstract

The purpose of the work is to develop a model for predicting changes in the functional state of athletes engaged in hand-to-hand combat, under the influence of a training load using psychophysiological indicators.

Material and methods. The study involved 24 male athletes who are professionally engaged in hand-to-hand combat with full contact with the opponent (full contact), and 20 athletes. The average age of the athletes was 19-26 years. Research methods: analysis of scientific and methodological sources, psychophysiological, mathematical statistics, fuzzy logic.

Results. The conducted studies proved the presence of significant differences in the values of psychophysiological indicators and the reaction to the training load of athletes with different levels of fitness, which made it possible to use these indicators to build a model for predicting the dynamics of a functional state. Changes in the functional state, determined by psychophysiological indicators, confirmed by corresponding changes in indicators of heart rate variability. The developed forecast model allows using two psychophysiological indicators (the time of a complex visual-motor reaction and the response index to a moving object), received to the load, to predict a change in the functional state of athletes engaged in hand-to-hand combat, with an overall accuracy of 95.5%. The forecast of changes in the functional state provides the trainer with the opportunity to timely adjust the volume of training loads and training regimen.

Conclusions. Significant differences between groups of trained athletes and beginners in terms of the state of nervous processes (the time of a complex visual-motor reaction and the response index to a moving object) to the load were revealed, which allowed developing a model for predicting the functional reaction to the load in athletes with different levels of sportsmanship. Using the obtained model allows predicting changes in the functional state of athletes that will take place under the influence of the test load, according to psychophysiological indicators without using the load with an overall accuracy of 95.5%.

Key words: hand-to-hand combat; psychophysiological indicators; fuzzy logic; forecast model

Анотація

Кочина М.Л., Чернозуб А.А., Адамович Р. Г., Кочин О.В., Фірсов О.Г. Модель прогнозу зміни функціонального стану спортсменів, що займаються рукопашним боєм, під впливом тренувального навантаження

Мета роботи – розробка моделі прогнозу зміни функціонального стану спортсменів, що займаються рукопашним боєм, під впливом тренувального навантаження з використанням психофізіологічних показників.

Матеріал і методи. В дослідженні взяли участь 24 спортсмени чоловічої статі, які професійно займаються рукопашним боєм з повним контактом з супротивником (фул-контакт), та 20 спортсменів-початківців. Середній вік спортсменів становив 19-26 років. **Методи дослідження:** аналіз науково-методичних джерел, психофізіологічні, математичної статистики, нечітка логіка.

Результати. Проведені дослідження довели наявність достовірних відмінностей у значеннях психофізіологічних показників та реакції на тренувальне навантаження спортсменів з різним рівнем тренуваності, що дозволила використати ці показники для побудови моделі прогнозу динаміки функціонального стану. Зміни функціонального стану, визначені за психофізіологічними показниками, підтверджені відповідними змінами показників варіабельності серцевого ритму. Розроблена моделі прогнозу дозволяє за двома психофізіологічними показниками (часом складної зорово-моторної реакції та індексом реакції на рухомий об'єкт), одержаними до навантаження, прогнозувати зміну функціонального стану спортсменів, що займаються рукопашним боєм, з загальною точністю 95,5%. Прогноз зміни функціонального стану надає тренеру можливість своєчасно корегувати обсяги тренувальних навантажень та режими тренувань.

Висновки. Виявлені достовірні відмінності між групами тренуваних спортсменів та початківців за показниками стану нервових процесів (часом складної зорово-моторної реакції та індексом реакції на рухомий об'єкт) до навантаження дозволили розробити моделі прогнозу функціональної реакції на навантаження у спортсменів з різним рівнем спортивної майстерності. Використання отриманої моделі дозволяє прогнозувати зміни функціонального стану спортсменів, які відбудуться під впливом тестового навантаження, за психофізіологічними показниками без використання навантаження з загальною точністю 95,5%.

Ключові слова: рукопашний бій; психофізіологічні показники; нечітка логіка; модель прогнозу

Аннотация

Кочина М.Л., Чернозуб А.А., Адамович Р. Г., Кочин О.В., Фірсов О.Г. Модель прогноза изменения функционального состояния спортсменов, занимающихся рукопашным боем, под влиянием тренировочной нагрузки

Цель работы – разработка модели прогноза изменения функционального состояния спортсменов, занимающихся рукопашным боем, под влиянием тренировочной нагрузки с использованием психофизиологических показателей. **Материал и методы.** В исследовании приняли участие 24 спортсмена мужского пола, которые профессионально занимаются рукопашным боем с полным контактом с противником (фул-контакт), и 20 спортсменов. Средний возраст спортсменов составил 19-26 лет. Методы исследования: анализ научно-методических источников, психофизиологические, математической статистики, нечеткая логика.

Результаты. Проведенные исследования доказали наличие достоверных различий в значениях психофизиологических показателей и реакции на тренировочную нагрузку спортсменов с различным уровнем тренированности, которая позволила использовать эти показатели для построения модели прогноза динамики функционального состояния. Изменения функционального состояния, определенные по психофизиологическими показателями, подтвержденные соответствующими изменениями показателей вариабельности сердечного ритма. Разработанная модели прогноза позволяет по двум психофизиологическими показателями (время сложной зрительно-моторной реакции и индексом реакции на движущийся объект), полученными к нагрузке, прогнозировать изменения функционального состояния спортсменов, занимающихся рукопашным боем, с общей точностью 95,5%. Прогноз изменения функционального состояния предоставляет тренеру возможность своевременно корректировать объемы тренировочных нагрузок и режима тренировок.

Выводы. Виявлені достовірні відмінності між групами тренуваних спортсменів та починаючих по показателям стану нервових процесів (время сложной зрительно-моторной реакции и индексом реакции на движущийся объект) к нагрузке позволили разработать модель прогноза функциональной реакции на нагрузку у спортсменов с различным уровнем спортивного мастерства. Использование полученной модели позволяет прогнозировать изменения функционального состояния спортсменов, которые состоятся под влиянием тестовой нагрузки, по психофизиологическими показателями без использования нагрузки с общей точностью 95,5%.

Ключевые слова: рукопашный бой; психофизиологические показатели; нечеткая логика; модель прогноза.



Introduction

Today's high-achieving sport places significant demands on the functional state of athletes. In the process of improving sportsmanship training and competitive load on the physiological systems of the athlete is constantly increasing. This can cause not only an increase in the level of adaptation-compensatory reactions, but also negative shifts in the functional systems of the body of athletes, lead to overtraining, the emergence of donological and pathological conditions. Assessment of the functional state of athletes at rest and predicting its changes in the dynamics of training require the creation of methods and models that allow to obtain and process information, to calculate appropriate indicators that can serve as markers of adverse changes in the body, to classify states and to develop prevention and rehabilitation measures.

Assessment of changes in functional status in the process of training and competitive loads can be performed according to the indicators of the electrocardiogram [1, 2, 3, 4], heart rate variability [5, 6, 7, 8, 9], external respiration function [10], various biochemical indicators [11, 12, 13, 14, 15], and indicators of psychological status [16, 17].

Different indicators can be used to develop models for predicting changes in athletes' functional status in training dynamics. Among the most studied are the indicators of the cardiovascular system and indicators of heart rate variability [18, 19], statodynamic stability [20], indicators of the central nervous system [21], etc.

According to Shinkaruk [22], forecasting in sports is the first stage in managing the process of sports training. Predicting the possible consequences of using training technologies, taking into account the individual capabilities of athletes allow the coach to achieve significant results [23, 24]. But this prediction is purely subjective, based on the personal experience and intuition of the coach and is inherent in him. Kuan et. al. [25] consider that to make the forecasting process objective, appropriate criteria are needed and mathematical forecasting models developed using them.

One of the most important systems of the body of athletes is the central nervous system, the fundamental properties of which are the peculiarities of mental and physiological processes, temperament, character, set of prevailing feelings and motives of activity. Combining the properties of the central nervous system is purely individual and in each case can contribute to the professional success of athletes, or vice versa, can be an obstacle to high achievements.

Important characteristics of the central nervous system include sensorimotor reactions (simple visual-motor response and complex visual-motor response, which combine sensory and motor components of mental activity. Simple and complex visual-motor reaction characterize the features of the nervous processes in athletes, Martial Arts Quick and Accurate Response to Incentives When Determining Simple and Complex Visual Motor Response Time Indicates Responsive Athlete Responses Against Action during the hand-to-hand combat, which, according to Kuan et al. [25], is the key to success.

According to the results of numerical studies Makarenko et. al. [12] believed that the individual typological qualities of athletes can be determined by the strength, mobility and dynamism of the nervous system [26]. Characteristics of sensory functions of athletes of different specializations were studied by Rovniy [27]. The strength of the nervous processes characterizes the functional endurance of the central nervous system, as well as the ability to concentrate the excitation process. Smaller values of the index of the strength of the nervous process indicate the better for the combat ability of athletes [28].

Functional mobility of nervous processes characterizes the ability to switch from performing one motor action to another. The smaller the value of this indicator, the faster is the change of the CNS states, which provides better adaptation to the difficult conditions of hand-to-hand combat.

The dynamics of nerve processes according to Tropin [3], Iermakov et.al [29] characterize the ability to form reactions that are adequate to external conditions. The smaller the dynamics of nervous processes, the faster the corresponding reactions of the central nervous system to changes in external conditions are formed.

Useful information about the psychophysiological state of hand-to-hand athletes can be obtained by determining the response rates of a moving object [30]. These indicators include the ratio of the reaction time that occurred before the test stimulus (anticipation) and the delay time when the reaction occurred after the test stimulus, as well as the ratio of the number of anticipation reactions to the number of delay reactions, which characterizes the ratio of excitation and inhibition reactions in the central nervous system. The indicator can evaluate the equilibrium of processes in the cortex of the athlete's brain [31, 32]. The success of athletes in hand-to-hand combat depends more on arousal processes that provide a quick response to external stimuli.

The hypothesis of the study is the assumption that changes in psychophysiological indicators in the dynamics of training and competitive load can be



used to assess the functional status of athletes, as well as to develop forecast models.

The purpose of the work is to develop a model for predicting changes in the functional state of hand-to-hand athletes under the influence of training load using psychophysiological indicators.

Material and methods

Participants

Under our observation, there were 24 male athletes professionally engaged in hand-to-hand combat with full contact with the enemy (full contact - Group I), and 20 beginner athletes (beginners - Group II). The average age of athletes was 19-26 years. The first group consisted of 3 international-class masters of sports, 8 masters of sports, 10 candidates for sports masters, and 3 first-graders. The second group consisted of athletes engaged in hand-to-hand combat at the amateur level. All athletes agreed to participate in the study.

Procedure

Registration of the studied parameters was carried out before and immediately after the training load. Training in both groups took place over 1.5 hours. The structure of the training and the level of exercise were developed in accordance with the level of physical fitness of the athletes.

The study of psychophysiological indicators was performed using the device "PFI-1" chronoreflexometer (LLC "ASTER-ITI", Kharkov). A PFI rhythmograph-1 device (ASTER-ITI LLC, Kharkov) with EasyHRV software package was used for cardiac signal registration.

The following psychophysiological indicators were determined in all athletes: functional mobility of nervous processes, strength of nervous processes, dynamic of nervous processes, simple visual-motor reaction and complex visual-motor reaction, as well as time of advance, time of delay, number of reactions of anticipation, number of reactions of delay test for the speed of reaction to a moving object. The moving response rate for a moving object was calculated by the moving object response index, which was equal to the module in relation to the lead time to the delay time.

To verify changes in the functional state of athletes before and after loading in them were determined indicators of heart rate variability, which according to Adamovich RG. with co-authors reflect the current FS of athletes and its changes [33].

Functional status information was obtained using two measurement circuits. The main circuit

consisted of a computerized chronoreflexometer, which allows a comprehensive study of the functional response of athletes to various stimuli by standard psychophysiological techniques [26, 28]. The obtained indicators of the state of nervous processes were stored in the study database and used for further analysis. An additional circuit formed by a computerized cardiograph allows synchronization with the main circuit to record a cardiogram. Indicators of heart rate variability, stored in the study database, allowed to conduct a cross-analysis of the functional status of the subjects.

Statistical analysis

Fuzzy Zadeh logic was used to develop a model for predicting changes in functional state under the influence of training load [34]. Statistical analysis of the results of the study was performed using descriptive statistics (with determination of mean values and mean square error). In the presence of a significant variation of indicators, medians (Me) and quartiles (25%; 75%) were determined. The significance of the differences between the indicators was assessed using the non-parametric Mann-Whitney criteria (independent samples) and Wilcoxon (dependent samples) [35]. The significance of the obtained results was determined at 95%.

Results

The test load used to develop a model for predicting changes in the functional state of trained athletes is given in Table. 1. The proposed first group test load in structure and content corresponds to the standard training of athletes engaged in melee combat. The load offered to beginners differed in content and time of exercise and corresponded to their level of fitness.

In the table. 2 shows the average values of certain psychophysiological indicators of athletes of both groups before and after exercise.

Further analysis and modeling of the change of functional state under the influence of the test load were performed according to the procedures shown in Fig. 1.

From the database of the results of the study were taken indicators of the variability of cardiac rhythm and state of nervous processes and calculated the change in their absolute values by subtracting the initial values from the final ones. These changes were then analyzed and hypotheses were made regarding the relationship between these changes in functional status and exercise load.



Table 1

Training structure of athletes engaged in hand-to-hand combat that was used as a test load

Components of training	Structural components	Content of load	Time distribution, %	Intensity load, % of max.
Introductory part (20% of the time)	General training	General developmental exercises	5	30-40
	Special training		15	75-80
Main part (70% of the time)	Technical training	Special exercises	10	75-80
	Tactical training	Improvement of the technique of complex elements	15	75-80
	Callisthenics	Correction of correlation of structural components of tactical schemes taking into account technical skill, anthropometric data and development of explosive force	10	75-80
		Basic: Increase of the level of explosive force in the conditions of anaerobic regime of energy-saving cookie.	10	75-80
	Integral preparation	Specialized: Increasing intramuscular and intramuscular coordination	25 10	75-80 -
		Implementation of technical skill in combination with the individual level of power development in the process of corrective sparring	10	-

Table 2

The average values of psychophysiological indicators of the subjects studied before and after loading

Terms of registration	Indexes	Groups	
		I (n=24)	II (n=20)
Before loading	Simple motor-visual reaction time (ms)	261,1±13,8	261,7±19,8
	Time of complex visual-motor reaction (ms)	361,5±21,4	396,9±55,6 ² U=83; Z=2,57; p=0,01
	Functional mobility of nerve processes (ms)	246,7±57,9	282,1±45,5
	Strength of nervous processes (ms)	406,1±74,7	442,9±80,2
	Number of anticipation reactions / Number of delay reactions (yo)	0,18 (0,11;0,96)	0,74 (0,18; 1,22) ² U=43; Z=2,29; p=0,021
	Moving Object Reaction Index	2,4±0,7	0,86±0,4 ² U=92; Z=2,29; p=0,021
	After loading	Simple motor-visual reaction time (ms)	242,7±21,1 ¹ Z=3,771; p=0,0002
Time of complex visual-motor reaction (ms)		337,0±32,5 ¹ Z=3,343; p=0,001	381,9±49,7 ² U=65; Z=2,95; p=0,003
Functional mobility of nerve processes (ms)		212,6±44,7 ¹ Z=2,57; p=0,001	203,3±60,2
Strength of nervous processes (ms)		343,6±73,4 ¹ Z=3,03; p=0,002	357,1±54,4 ¹ Z=3,03; p=0,002
Number of anticipation reactions / Number of delay reactions (yo)		0,67 (0,38; 1,22)	0,82 (0,43; 1,22)
Moving Object Reaction Index		0,9±0,5 ¹ Z=2,37; p=0,018	0,87±0,03

Notes: 1 - differences in the mean values obtained before and after training are valid according to the Wilcoxon criterion; 2 - differences in mean values of group I and group II indicators are significant by the Mann-Whitney test ($p < 0.05$); for the indicator Number of anticipation reactions / Number of delay reactions (yo) medians and quartiles were calculated (25%; 75%); n is the number of athletes in the group

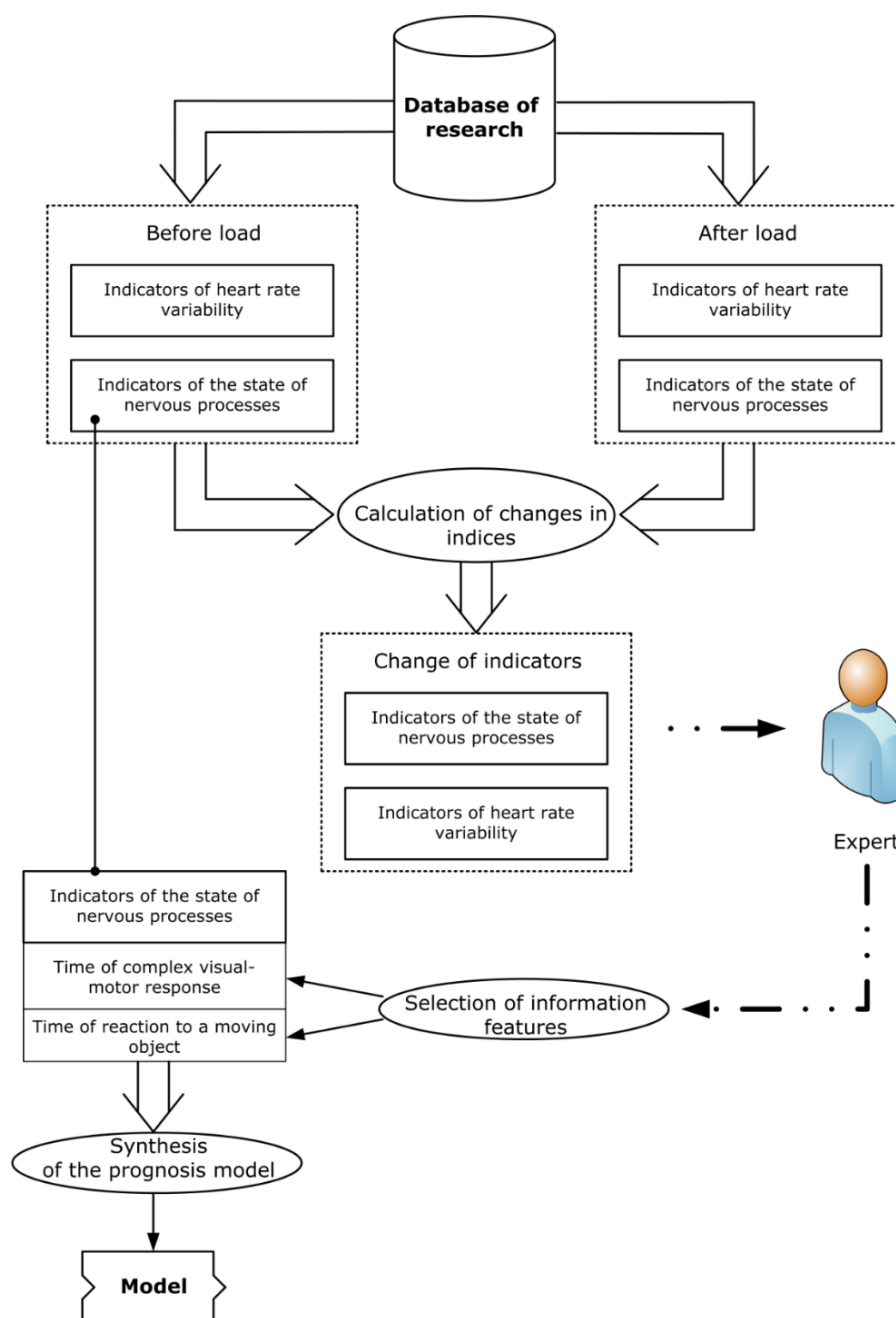


Fig. 1. Procedure for analysis of functional state indicators and simulation of reaction to test load

Analysis of changes in heart rate variability using fuzzy clustering according to the fuzzy c-mean algorithm revealed that all athletes who are new to the dynamics of change in heart rate variability under the influence of load belong to the cluster of its perception, indicated by the index t , and λ , which is indicated by index 1. That is, the response to the load of athletes of the studied groups was different. Significant differences in the load between groups of athletes were found only in the proportion of investigated indicators of heart rate variability [33], but after the load almost all indicators differ

significantly. On the other hand, significant differences were found between the studied groups of athletes by the indicators of the state of nervous processes before loading, namely the time of complex visual-motor reaction (ms) and the index of reaction to a moving object (cu) (Table 2).

According to these two indicators, a model for predicting the functional response to loading in athletes with different levels of athletic skill was synthesized.

The procedure of synthesis of the model of forecasting the reaction to load in graphical form is



shown in Fig. 2. To obtain fuzzy rules, a matrix was formed from previously selected indicators of the state of nervous processes, namely: the time of complex visual-motor reaction (ms) and the index of reaction to a moving object (cu). These data were supplemented by a column indicating which load sensing group (1 or 2) the athlete was assigned to. Complex visual motor response time (ms) and response index for a moving object (cu) were subjected to subtractive clustering (a mountain clustering algorithm) developed by Yager et. al. [36]. The parameters of the clustering algorithm were set in accordance with the recommendations of the Scilab package. Each received cluster was matched by one fuzzy rule, and the coordinates of the cluster centers were the coordinates of the maximum of the membership functions, which used the Gaussian function [37]. According to the received logical rules and membership functions, a set of linear functions is formed, which links the logical rules and data of the corresponding load perception group (1 or 2). Formal recording of a system of fuzzy equations, a

set of coordinates of centers and parameters of compression-stretching and linear equations of forms is a model of forecast. In the process of model synthesis, the procedure of adjusting it was performed, which consisted of cyclic modification of the parameters of compression - stretching of the membership function and coefficients of linear functions to minimize the error of the forecast using the model.

The scheme of using the model of prediction of change of functional state under the influence of the test load is shown in Fig. 3. Using the obtained model will allow to predict changes in the functional state of athletes that will arise under the influence of test load according to certain psychophysiological indicators. It is enough to define only two indicators: time of complex visual-motor reaction (ms) and index of reaction to the moving object (cu). Validation of the prediction model using indicators of 20 non-training athletes showed an overall accuracy of 95.5%.

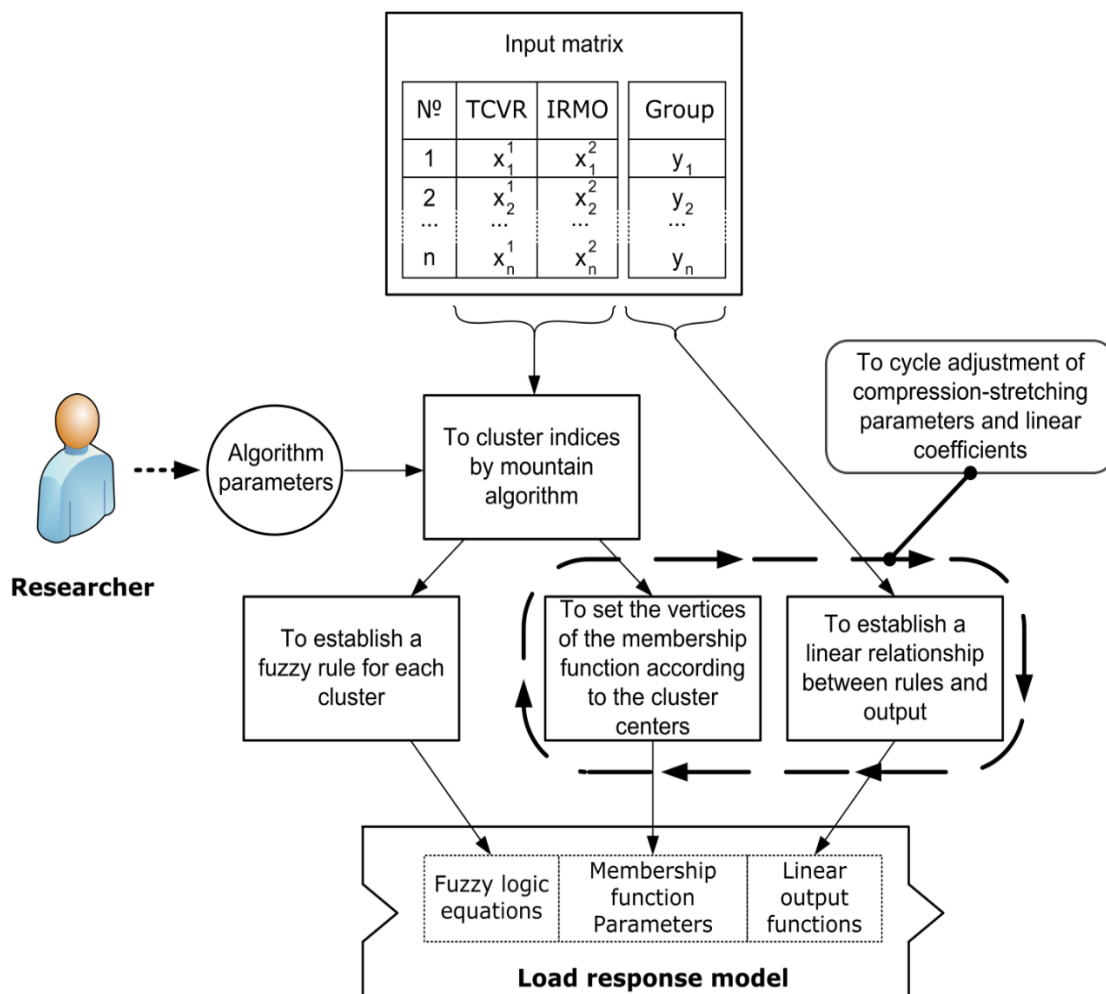


Fig. 2. Procedure of synthesis of model of predicting change in the functional state of an athlete under the influence of load

Discussion

According to the Table. 2, it can be noted that the Simple Motor-Response Time (ms) and the Complex Visual-Motor Response Time (ms) are significantly reduced after loading in the first group and practically do not change in the second. In addition, there are significant differences in the time of complex visual motor response (ms) between the first and second groups before and after loading. Initial values Functional mobility of nerve processes (ms) and Strength of nerve processes (ms) in athletes of the studied groups did not differ significantly, after loading these indicators decreased significantly in the first groups. When examining the results of a test for the response rate of a nra, a moving object to the load found that significantly more balanced processes in the nervous system are observed in trained athletes, as evidenced by the number of anticipation reactions / the number of delay reactions (cu). After loading, this indicator is close in value in both groups. Also, prior to loading, the groups differed significantly in the Moving Object Reaction Index (cu).

Our previous studies of the dynamics of heart rate variability indicators [2] showed that before the

test load, there were significant differences between the studied groups only in the vegetative rhythm index, the adequacy of the regulation processes, as well as the spectral characteristics. After loading, virtually all indicators of heart rate variability in the athletes of the studied groups differed significantly. This confirmed the presence of reliable response of the body of athletes to the test load and sensitivity to changes in the functional state of certain psychophysiological indicators.

Thus, the data obtained confirm the different response of the athletes of the studied groups to the training load. On the other hand, the presence of significant differences in psychophysiological indicators between the studied groups made it possible to use these indicators to build a model for predicting the dynamics of the functional state.

Physical activity causes each athlete appropriate changes in functional status, which can be classified as a norm of reaction or indicate a pre-existing or pathological condition. The proposed scheme (Fig. 3) identifies two ways of changing the functional state.

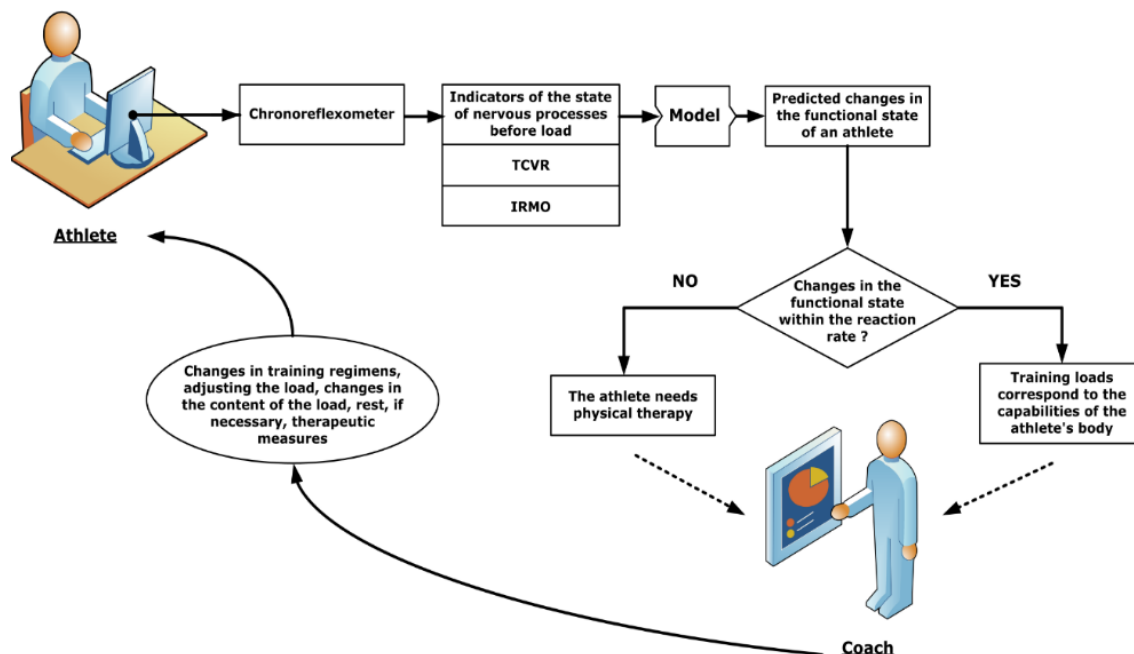


Fig. 3. Scheme of using models of predicting changes in the functional state of athletes under the influence of test load

If the predicted functional state changes relate to the normal reaction, ie the athlete enters cluster 1 in response to the load, training can be carried out according to the scheme corresponding to the current stage of training. If, as a result of using the prediction model, the athlete falls into cluster 2, then normalization of his functional state is required, which includes not only correction of the training

process, but also more in-depth medical examination and appropriate rehabilitation measures in order to prevent overtraining, occurrence of pathological or pathological changes.

Predictive approaches in sports can be divided into two groups. The first group includes the prediction of success in training or competitive activities, the second - changes in the functional state



of athletes under the influence of training (competitive) loads.

Predicting the success of athletes' competitive activity is described in a large number of papers in which the authors study different changes in functional status indicators, morphofunctional indicators, model characteristics of athletes of a particular sport, previous success, and indicate that they can predict changes in functional status, efficiency. But there is no prediction mechanism or real model of forecast itself. For example, comparisons with model characteristics and the statement that for athletic success in adult sports athletes must be runners-up in youth are suggested by Latishev [26]. The approach proposed by the author to predict sports performance is not supported by the results of the use of any statistical criteria or methods and is verbal [38].

Volodchenko [39] proposes to use a table in which to score the scores of 31 varied athletes, whose determination requires the use of a large number of instrumental techniques to obtain a prediction of competitive performance in kickboxing. Prediction of the proposed approach requires the preliminary determination of all indicators and the calculation of the forecast threshold according to the proposed table, that is, there is a time-consuming process of estimating a large number of indicators in manual mode, which reduces the effectiveness of the proposed methodology.

Currently, there are a number of works in which predictions in sports are constructed using modern methods of data mining - neural networks, fuzzy logic, discriminant, correlation-regression and factor analysis [40, 41, 42].

For example, Yavorska [16] proposed a program for predicting the performance of athletes based on their specific sports parameters using a complex mathematical approach, which includes vector and matrix analysis, variance and factor, as well as the theory of multidimensional linear regression in Euclidean space. Glotov et. al. [43] proposed, by a large number of indicators characterizing the functional status of athletes and their genotypes, to create regression models that allow one to determine the most informative ones and predict success in certain sports. Baranaev [44], using correlation structures of indicators of young athletes, revealed the criteria for the selection and prediction of athletes' success at the stage of sports specialization.

Thus, the use of modern methods of data analysis allows to obtain reliable new results, to build models of forecasting changes in the functional state of athletes under the influence of load, the success of

athletes in certain sports, to determine the criteria for sports selection.

The developed model allows to predict, by two psychophysiological indicators (Time of complex visual-motor reaction (ms) and Index of reaction to the moving object (uo)), the functional state of hand-to-hand athletes, with probability 95, 5%. The prognosis of the change of the functional state gives the trainer the opportunity to adjust the amounts of training loads and training regimes in a timely manner.

Conclusions

1. Significant differences between groups of trained athletes and beginners by the indicators of the state of nervous processes of time of complex visual-motor reaction and the index of speed of reaction to a moving object to the load were revealed, which allowed to develop a model of forecasting of functional reaction to loading in athletes with different level of sportsmanship.

2. It is shown that physical activity causes in each athlete corresponding changes in the functional state, which can be classified as a norm of reaction or indicate a donological (pathological) state. If the predicted functional state changes relate to a normal reaction, the training may be performed according to a pattern consistent with the current preparation stage. Otherwise, the normalization of the functional state, which includes not only the correction of the training process, but also more in-depth medical examination and appropriate rehabilitation measures to prevent adverse conditions, is required.

3. Using the obtained model will allow predicting changes in the functional state of athletes under the influence of test load on psychophysiological indicators without using a load with an overall accuracy of 95.5%, which allows the trainer to timely adjust the amount of training loads and training regimes.

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Conflict of interest

Authors state no conflict of interest.



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