Physiological mechanisms determining the performance of passing control standards for physical culture

UDC 796.01:612

I.M. Mazikin[1]
Dr. Med., Professor **M.M. Lapkin**[1]
Dr. Med., Professor **R.A. Zorin**[1]
Dr. Med., Professor **A.L. Pokhachevsky**[1, 2]
PhD, Associate Professor **M.V. Akulina**[1]
[1]I.P. Pavlov Ryazan State Medical University, Ryazan
[2]I.M. Sechenov First Moscow State Medical University, Moscow

Corresponding author: sport_med@list.ru

Abstract

Objective of the study was to identify significant physiological mechanisms of performance formation when passing control standards in physical culture and to establish the relationship between performance indicators and individual psychophysiological characteristics.

Methods and structure of the study. 120 young men aged 18-20 years old belonging to the main health group were examined. With the help of cluster analysis, groups were identified with different performance in passing control standards in terms of speed endurance and speed-strength indicators. To solve the problem of classifying students, taking into account their psychophysiological characteristics, an artificial neural network (ANN) was created, distributing students into groups with specified characteristics.

Results and conclusions. When analyzing the motivational basis of behavior, it was revealed that the students of the first cluster were dominated by an internal motive and the motive of focusing on success, with at the same time high rates of assessing their potential. The students of the second cluster were dominated by the motive for assessing the significance of the result of activity. Statistically significant differences in personal psychophysiological characteristics and indicators of physical performance were established in the subjects of the identified clusters. On the basis of a set of data obtained, cluster analysis and ANN technology made it possible to predict the performance of students with a high probability, as well as to rank indicators according to their significance for the formation of unequal performance.

Keywords: *psychophysiological characteristics, cluster analysis, artificial neural networks.*

Introduction. The level of physical fitness as the ratio of the effectiveness of activity and physiological costs for its implementation is the key concept of sports physiology [2, 5, 12]. An important factor determining the effectiveness of purposeful human activity is the interaction of such physiological mechanisms as psychophysiological features [4, 7, 15], indicators of dynamic functional lateralization [1], physical performance, and the motivational basis of behavior [6, 10]. The functioning of the mechanisms that reflect the effectiveness of sports activities from the standpoint of systemic physiology is associated with the "physiological price" of the result of an activity [13, 16], which determines one of the aspects of its effectiveness.

Today, the formation of a person's physical fitness is considered as a complex systemic phenomenon. In accordance with the theory of functional systems, the effectiveness of purposeful human activity is ensured by the interaction of various physiological mechanisms [11, 14]. At the same time, psychophysiological characteristics in conjunction with the results of sports activities can serve as markers of the systemic organization of purposeful activities carried out with different results [5].

Objective of the study was to identify significant physiological mechanisms of performance formation when passing control standards in physical culture and to establish the relationship between performance indicators and individual psychophysiological characteristics.

Methods and structure of the study. Statistical data processing was carried out using the Statistica 13.0 software package. Quantitative indicators were assessed for compliance with the normal distribution using the Shapiro-Wilk test. Cluster analysis (k-means method) was used to identify groups. The median

Table 1. *Characteristics of the implementation of control standards*

Indicator	Group 1			Group 2			U (Z)	p
	Me	LQ	UQ	Me	LQ	UQ		
100 m run, s	12,9	12,4	14,3	14,3	14,0	14,5	860,5	0,001
1000 m run, s	245,0	240,0	248,0	255,0	246,0	268,0	734,0	0,001
Standing long jump, cm	257,0	248,0	265,0	275,0	264,0	280,0	716,5	0,001
Pull-ups, times	12,0	10,0	12,0	15,0	14,0	17,0	264,5	0,001

(Me), upper (UQ), and lower quartile (LQ) were used to describe the study groups. A comparative analysis of the indicators was carried out using the nonparametric Mann-Whitney test (U) for paired independent samples [8].

The construction of an artificial neural network (ANN) was carried out in an automatic mode based on groups of a number of indicators: neuroenergy mapping (NEM) with registration of the level of constant potential (LCP) in leads Fz, Cz, Oz, Td, Ts; motivational basis of behavior (test for assessing the level of claims according to V.K. Gerbachevsky); psychodynamic characteristics (the general structure of V.M. Rusalov's temperament - ergicity, plasticity, pace and speed, emotionality, social ergicity, social plasticity, social tempo and social emotionality, as well as the type of behavioral activity); the level of basic physical performance with the calculation of the normalized indicator PWC_{170}; asymmetry coefficients (Annette questionnaire, lateral organization profile (PLO), motor and sensory asymmetries).

The selection of indicators was based on a consistent assessment of the improvement in the quality of the model. ANNs were characterized by a certain architecture, training performance, control and test performance [3]. The study was approved by the Local Ethical Committee at the Ryazan State Medical University of the Ministry of Health of Russia on April 11, 2021. All study participants signed an informed consent.

Results of the study and their discussion. By the method of cluster analysis, two groups of students were identified depending on the effectiveness of passing the control standards for physical culture (Table 1). Group 1 (70 people) was designated as "effective in running disciplines", and group 2 (50 people) – as "effective in strength disciplines".

The creation, training and testing of the ANN was carried out using the Statistica Basic Academic 13.0

Table 2. *Ranked list of indicators used by the ANN to predict the effectiveness of passing control standards*

Indicator	Rank	Sensitivity *
Internal motive	1	13,86
Cognitive motive	2	4,30
Significance of results	3	2,79
Assessment of the level of results achieved	4	1,74
PWC_{170} Test	5	1,48
The initial background (Td-Ts lead) of the NEM	6	1,41
Social tempo	7	1,26
Annette's questionnaire coefficient	8	1,14
Coefficient manual asymmetry	9	1,10
Anxiety level	10	1,08
Lateral Organization profile coefficient	11	1,05
Social plasticity	12	1,00
LCP Verbal fluency test (Ts lead) NEM	13	1,00
LCP Schulte-Platonov test (lead Td-Ts) NEM	14	1.00
LCP Verbal fluency test (Td-Ts lead) NEM	15	0,99
Source Background (Cz lead) NEM	16	0,96
LCP Test of fluency of verbal responses (lead Td) NEM	17	0,70

** – values are rounded to hundredths (differences in other digits are taken into account when ranking indicators by sensitivity).*

(Ru) software package. Machine learning technology assumed the use of an automatic advanced algorithm for creating and training ANNs in the mode of solving classification problems. Initially, an ANN was created using the following data as predictors: NEM (the level of constant potential of abduction Fz, Cz, Oz, Td, Ts), the motivational basis of behavior (the test for assessing the level of claims according to V.K. Gerbachevsky), psychodynamic characteristics (general structure of temperament V.M. Rusalova - ergicity, plasticity, pace and speed, emotionality, social ergicity, social plasticity, social tempo and social emotionality, as well as the type of behavioral activity), the level of basic physical performance (PWC_{170} (wt/kg), asymmetry coefficients (questionnaire Annette, lateral organization profile, motor and sensory asymmetries). The selection of indicators was based on a sequential assessment of the improvement in the quality of the model. This neural network was a multilayer perceptron with 17 input neurons, 17 intermediate layer neurons and two output neurons. The performance of the training sample was 100%, control - 100%, test - 100% (MLP 17-1 7-2; 100:100:100). In table. 2 shows the predictors used to solve the forecasting problem.

The use of ANN technology made it possible to solve the problem of classifying students by the effectiveness of passing control standards in physical culture based on a set of indicators, which has applied practical significance, and also allows ranking groups of indicators according to their classification significance. The sensitivity of this ANN in determining the effective group of practically healthy individuals was 100%; specificity - 100%.

The indicators of the motivational basis of behavior, the level of basic physical performance, indicators of dynamic functional asymmetry of the brain according to NEM criteria, indicators of psychodynamic characteristics and behavioral phenotypic lateralization were of the greatest importance for solving this problem. The mutual assistance of the indicated indicators of the systemic organization of the purposeful activity of the subjects of the identified clusters reflects the features and reasons for the formation of its various effectiveness.

Conclusions. The formation of physical fitness is associated not only with physical performance, but also with a certain combination of psychophysiological characteristics: anxiety, ergicity, plasticity, speed indicators of behavior, emotionality, focus on results, functional lateralization.

The effectiveness of passing control standards can be successfully predicted on the basis of a complex of physiological and psychophysiological indicators using cluster analysis and ANN technology. The proposed algorithm for solving the problem of distributing subjects into groups with a different set of physiological, physical indicators and psychophysiological characteristics suggests the possibility of its use in the practice of sports selection. The good classification ability of the algorithm allows solving the applied problem of predicting “effective in running disciplines” and “effective in strength disciplines”.

The obtained facts in the future will allow us to describe the optimal “psycho-physiological portraits of a person” that contribute to a certain direction of his physical fitness.

References

1. Bragina N.N., Dobrokhotova T.A. Funktsionalnyye asimmetrii cheloveka [Functional human asymmetries]. 2nd ed., rev., add.. Moscow: Meditsina publ., 1988. 240 p.
2. Danilova N.N., Krylova A.L. Fiziologiya vysshey nervnoy deyatelnosti [Physiology of higher nervous activity]. Rostov-on-Don: Feniks publ., 2005. 478 p.
3. Zorin R.A., Zhadnov V.A., Lapkin M.M. Opyt prakticheskogo ispolzovaniya tekhnologii iskusstvennykh neyronnykh setey v fiziologii i klinicheskoy nevrologii [Experience in the practical use of artificial neural networks technology in physiology and clinical neurology]. Proceedings national scientific conference, dedicated 70th anniversary of the founding of the I.P. Pavlov Ryazan State Medical University. Ryazan, 2013. pp. 25-28.
4. Lapkin M.M., Yakovleva N.V., Proshlyakov V.D. Issledovaniye psikhologicheskikh i fiziologicheskikh determinant uspeshnosti obucheniya studentov v meditsinskom vuze [Study of the psychological and physiological determinants of student learning success in a medical university]. Lichnost v menyayushchemsya mire: zdorovye, adaptatsiya, razvitiye. 2014. Vol. 4. No. 1. pp. 75-83.
5. Novikova A.P., Kotov A.V. Motivatsiya dostizheniya: psikhofiziologicheskiye korrelyaty i ikh dinamika v khode dlitelnogo obucheniya [Achievement motivation: psychophysiological correlates and their dynamics during long-term training]. Neyrokompyutery: razrabotka, primeneniye. 2011. No. 11. pp. 46-52.
6. Proshlyakov V.D. Otsenka fizicheskogo razvitiya i metodika trenirovki studentov [Assessment of physical development and methods of training students]. Guidelines for students. Ryazan: RyazGMU publ., 2007. 43 p.

7. Psikhofiziologiya [Psychophysiology]. Textbook for universities. Alexandrova Yu.I. [ed.]. St. Petersburg: Piter publ., 2007. 464 p.
8. Boev V.M., Borshchuk E.L., Ekimov A.K. et al. Rukovodstvo po obespecheniyu resheniya mediko-biologicheskikh zadach s primeneniyem programmy Statistica 10.0 [Guidelines for ensuring the solution of biomedical problems using the Statistica 10.0 program]. Orenburg: Yuzhnyy Ural publ., 2004. 208 p.
9. Saltykov A.B. Funktsionalnyye sistemy v meditsine [Functional systems in medicine]. Moscow: Meditsinskoye informatsionnoye agentstvo publ., 2013. 208 p.
10. Sudakov K.V. Motivatsiya i podkrepleniye: sistemnyye neyrofiziologicheskiye mekhanizmy [Motivation and reinforcement: systemic neurophysiological mechanisms]. Vestnik Novgorodskogo GU, 2006. No. 35. pp. 77-81.
11. Sudakov K.V., Umryukhin P.E. Sistemnyye mekhanizmy emotsionalnogo stressa [Systemic mechanisms of emotional stress]. Moscow: GEOTAR-Media publ., 2010. 112 p.
12. Fudin N.A., Vagin Yu.E. Sistemnaya organizatsiya sportivnoy deyatelnosti [Systematic organization of sports activities]. Vestnik novykh meditsinskikh tekhnologiy (elektronnyy zhurnal). 2013. No. 1 (2-82). pp. 1-5.
13. Brooks G.A., Fahey T.D., Baldwin K.M. Exercise physiology: human bioenergetics and its applications. NY: McGraw-Hill, 2005. 511 p.
14. Moein S. Medical diagnosis using artifi cial neural networks. Hershey: Medical Information Science Reference, 2014. 310 p.
15. Rektor I., Brazdil M., Nestrasil I. [et al.] Modifications of cognitive and motor tasks affect the occurrence of event-related potentials in the human cortex. The European Journal of Neuroscience. 2007. Vol. 26, № 5. pp. 1371-1380.
16. Parker A.G., Hetrick Sarah E., Anthony F. Jorm The effectiveness of simple psychological and physical activity interventions for high prevalence mental health problems in young people: A factorial randomised controlled trial. Journal of affective disorders. 2016. Vol. 196. pp. 200-209.