# Aerobic and anaerobic training: effects on cognitive function in adolescents

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Dr. Biol., Associate Professor **I.A. Krivolapchuk**[1]
PhD, Associate Professor **M.B. Chernova**[1]
[1]Institute of child development, health and adaptation, Moscow

Corresponding author: i.krivolapchuk@mail.ru

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**Abstract**

**Objective of the study** was to determine the impact of bioenergetic factors on the physical performance of young athletes during cognitive tasks of different difficulty levels.

**Methods and structure of the study.** The research project included a group of young athletes aged 13 to 14, who participated in cycling and running competitions over medium and long distances. The study involved 97 participants. The cognitive load was simulated using a two-minute task with letter tables in two modes: «autotemp» and «maximum tempo».

**Results and conclusions.** It has been shown that high aerobic, anaerobic glycolytic and anaerobic alactic capacity are associated with favorable changes in FS under conditions of intense cognitive load. The results of the study give reason to believe that the complex use of aerobic and anaerobic physical activity in the process of sports improvement creates the prerequisites for increasing stress resistance and optimizing the physical activity of the body of young athletes not only during muscular, but also intense cognitive activity.

***Keywords:*** *aerobic and anaerobic capacity, functional state, cognitive performance, cross-adaptation, adolescent athletes.*

**Introduction.** According to scientific research, physical performance (PP) and the body's bioenergetic capabilities largely determine the success of human adaptation to the effects of various unfavorable factors, including those of a psychosocial nature [1, 11, 4, 3, 9]. There is reason to believe that at different age periods, the influence of aerobic and anaerobic components of PP on the physiological, behavioral and subjective aspects of the functional state (FS) of the body may differ significantly due to the heterochronic and nonlinear development of key physiological systems and bioenergetic processes [4, 6, 8, 2]. In this regard, the ontogenetic aspect of studies of nonspecific cross-effects of adaptation to endurance loads, manifested in conditions of psychosocial stress and intense cognitive activity, is of particular interest. However, despite the available information, it must be acknowledged that there is a lack of work devoted to studying the «total» effect of the impact of the level of development of aerobic and anaerobic capabilities on changes in human FS during intense cognitive loads.

**Objective of the study** was to determine the impact of bioenergetic factors on the physical performance of young athletes during cognitive tasks of different difficulty levels.

**Methods and structure of the study.** The study involved young athletes aged 13-14 involved in cycling and running medium and long distances (n=97). The cognitive load model was a two-minute work with letter tables in the following modes: 1) «auto pace»; 2) «maximum pace». Based on the results of completing the test tasks, the volume of work (A) and the productivity coefficient (Q) were calculated. The -potential (OP), which characterizes the FS of the central nervous system, was recorded using a setup for studying the ultraslow biopotentials of the brain. The reactivity of the OP and the spontaneous relaxation time (SR)

were determined. Taking into account the duration of the test procedures, which limited the number of recorded R-R intervals, a time analysis of the heart rate variability was used. The average duration of the R-R interval (RRNN), mode (Mo), mode amplitude (AMo), spread of cardiointervals (MxDMn), standard deviation (SDNN), stress index (SI) and peak heart rate (HR) were calculated. Systolic (SD) and diastolic (DD) blood pressure were recorded in accordance with the recommendations of the Society for Psychophysical Research. The mean pressure (SBP), double product (DP), Myznikov index (MI), and circulatory efficiency index (MP/HR) were calculated. To determine the psychophysiological «price» of activity, Q/SI, Q/HR, Q/DP, A/SI, A/HR, A/DP were found. To diagnose anxiety, the Kondash, Phillips, Luscher tests, Hornblow visual analog scale (HAVS) were used; well-being (W) and mood (M) - the SAN test. Aerobic (factor A), anaerobic glycolytic (factor B) and anaerobic alactic (factor C) abilities were diagnosed based on complex assessments, including four informative indicators, identified as a result of factor analysis. Subsequently, dispersion analysis of three-factor orthogonal complexes was performed, allowing to evaluate the influence of each factor separately (A, B, C) and their interaction (AB, AC, BC, ABC).

**Results of the study and discussion.** It was found that bioenergetic capabilities have a pronounced effect on the physical fitness of young athletes under intense cognitive loads (table): with regard to 46 physiological, behavioral and subjective indicators, the null hypothesis is refuted at a high significance level ($p<0,05-0,01$). It was shown that the differences between the group means of the complex of variables under consideration are not random and are largely determined by the level of development of the bioenergetic components of physical fitness. Aerobic capabilities significantly affect seven, anaerobic glycolytic – two, anaerobic alactate – four physical fitness indicators (see table). It is evident that the aerobic component of physical fitness affects the greatest number of the studied parameters, which is consistent with the results of comparing adolescent athletes who differ in individual indicators of aerobic performance – $VO_{2max}$

*Significant influence of aerobic (factor A), anaerobic glycolytic (factor B), anaerobic alactate (factor C) components of performance on the physical fitness indicators of young athletes*

| Indicator | Factors | Influence, ($h_x^2$), % | Indicator | Factors | Influence, ($h_x^2$), % |
|---|---|---|---|---|---|
| MxDMn0, ms | A+B+C | 11,03* | SD0, mmHg | A | 6,71** |
| MxDMn1, ms | A+B+C | 12,05* | SD1, mmHg | B | 7,10* |
| MxDMn2, ms | A+B+C | 11,48* | SD1, mmHg | C | 6,20* |
| SDNN1, ms | A+B+C | 10,56* | SD2, mmHg | B | 6,10* |
| AMo0, % | A+B | 5,90* | HR2, bpm | A+B+C | 17,40** |
| AMo1, % | A+B+C | 12,02* | A2, characters | A+C | 8,54* |
| AMo2, % | B+C | 10,63* | Q2, rel. units | A+C | 10,60** |
| AMo2, % | A+B+C | 19,26** | A/SI1, rel. units | A+B+C | 16,87** |
| HRV, min | A+C | 8,07* | Q/SI1, rel. units | A+B+C | 14,68** |
| DP0, mmHg | A+C | 9,89* | A/HR2, rel. units | A+C | 7,79* |
| DP1, mmHg | A+C | 8,36* | A/SI2, rel. units | A+B+C | 10,87* |
| DP2, mmHg | A | 4,04* | A/DP2, rel. units | A+C | 6,36* |
| DP2, mmHg | A+B+C | 11,16* | Q/HR2, rel. units | A+C | 10,14** |
| SI1, rel. units | A+B+C | 10,54* | Q/DP2, rel. units | A+C | 9,16** |
| SI2, rel. units | A+B+C | 12,45* | ZASHT, mm | C | 7,18* |
| RRNN2, s | A+B+C | 10,40* | C, score (before lessons) | A | 8,23** |
| Mo2, s | A+B+C | 15,53** | H, score (before lessons) | A | 3,81* |
| OP1, mV | A+B+C | 13,77** | H, score (before lessons) | A+B+C | 9,34* |
| OP2, mV | A+C | 10,86** | C, score (after lessons) | A | 9,66** |
| SBP0, mmHg | A | 5,80* | A, score (after lessons) | B+C | 11,60* |
| SBP1, mmHg | C | 5,60* | H, score (after lessons) | A | 4,63* |
| SBP2, mmHg | C | 7,91* | School anxiety, score | A+B | 8,76* |
| SP/HR2, rel. units | A+B+C | 17,52** | Social stress, score | A+B+C | 10,96* |

***Note**: 0 - background state; 1 - work in auto-tempo mode; 2 - work in maximum tempo mode. *, ** - statistically significant effect at $p<0.05$ and 0.01, respectively.*

and $PWC_{170}$ (see figure). In this case, the differences were manifested in relation to 20 and 14 indicators, respectively.

Pronounced functional effects were noted in relation to the mutual influence of the considered components of the FS (see the table). The interaction of ABC was significant in relation to 19, AC – 10, BC – two, AB – two variables. The strength of the influence of factors for various FS indicators was in the range from 4,0 to 19,3%, and the total effect of several combinations of factors reached 29,9%. The obtained results show that the combination of high levels of development of aerobic and anaerobic capabilities provides a pronounced functional effect in relation to the physiological, subjective and behavioral aspects of the FS. The positive interaction of the bioenergetic components of the FS is reflected in the indicators of psychophysiological cost, efficiency and vegetative support of cognitive activity, as well as the emotional state.

It is assumed that the specificity of the FS of the body under conditions of intense cognitive activity, caused by the peculiarities of the development of aerobic and anaerobic components of the FS, is manifested at different structural and functional levels of the organization of the living system [1, 2, 7]. Apparently, adaptive changes in the body of young athletes who use loads in the process of sports training that develop aerobic and anaerobic endurance, determine the formation of universal adaptive reactions that increase resistance to the combined effects of various unfavorable factors.

The key mechanisms for the formation of positive cross-effects of adaptation are: the development of general algorithms for the rapid deployment of programs for the «reassignment» of vegetative and motor elements that form a common final path for any adaptive reaction; improvement of the activity of the antihypoxic defense system, activated during physical and cognitive loads [1]. The existence of differences between adolescent athletes with different FR in relation to psychophysiological reactivity to cognitive load indicates the peculiarities of the functioning of the modulating system of the brain. An important mechanism of the optimizing effect of a high level of FR on the FS is probably an increase in functional capabilities and a change in the nature of the interaction of the main stress-realizing and stress-limiting systems.

There is evidence that physical exercise helps improve brain function at the structural, functional and molecular levels. At the molecular level, these changes are represented by mechanisms that contribute to increased brain plasticity (BDNF, NGF, IGF-1, VEGF); at the structural level – to improved synaptic plasticity and activation of neurogenesis; at the functional level – to behavioral development (improved performance efficiency, inhibitory control, cognitive flexibility, decreased anxiety, depression, increased stress resistance). It is important to note that the reactivity of the autonomic nervous, sympathetic-adrenal, hypothalamic-pituitary and cardiovascular systems during psychosocial stress and intense cognitive loads is closely related to the magnitude of physiological changes under physical work conditions [11, 1, 10, 5, 9].

**Conclusions.** It has been established that the bioenergetic components of the FR have a significant effect on the physiological, subjective and behavioral aspects of the FS of young athletes aged 13-14 years under intense cognitive load. High aerobic, anaerobic glycolytic and anaerobic alactate productivity of the body, both separately and in interaction, cause a decrease in the psychophysiological «price» and an increase in the effectiveness of intense activity, an improvement in well-being and mood, and a decrease in anxiety.

The results obtained give reason to believe that the complex use of loads of various metabolic orientations in the process of sports improvement can contribute to the formation of stress resistance and the «limitation» of excessive psychophysiological reactivity.

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