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Original Article

Biochemical monitoring of different training regimens of 16-year-old water polo players

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Abstract.
Biochemical monitoring of the adaptation of 16-year-old water polo players to physical activity specific to this kind of sport is of immense importance. The content and objectives of biochemical monitoring are enhanced due to the fact that this cohort undergoes the second phase of puberty. Exercise regulation should be strictly dosed according to the adaptive capabilities of young athletes. It is this phase of puberty that is sensitive to the development of such a physical quality as strength. The sport training has a positive influence only in the absence of stress response of the body of adolescent athletes. At the same time, physical activity should promote the development of physical qualities. This article proposes a scheme of biochemical monitoring of a standard training of 16-year-old water polo players on land and in water. Based on the results of performed analysis we have come to the conclusion that the training regimen in both cases promotes the development of anaerobic characteristics. In particular, to a greater extent in the pool (according to the data from lactic acid excretion). The results of urea excretion showed better development of aerobic characteristics on land. In general, the energy quality of training activities (in terms of inorganic phosphorus excretion) was approximately the same under conditions of their performance both on land and in the pool. It is also important to observe the absence of a difference between the parameters of inorganic phosphorus after exercise compared to the state of relative rest. This energy situation of young athletes' bodies indicates their approach to the state of energy systems of adults. Thus, we conclude that the training process is adequate for 16-year-old athletes. This is indicated by shifts in biochemical markers of adaptation to training loads of both anaerobic and aerobic energy systems of the studied young water polo players. Therefore, the proposed scheme of biochemical monitoring can be offered as a model example of control over the adaptive changes of 16-year-old water polo players during their annual training cycle.
Key words: biochemical monitoring, lactic acid, urea, inorganic phosphorus, 16-year-old water polo players, training regimen, anaerobic and aerobic adaptation of energy systems.

Introduction.

The physical qualities of a person, which are manifested during muscular work (strength, types of speed, agility, endurance, etc.), first of all depend on the biochemical characteristics of a person in the conversion of chemical energy into mechanical energy. The study of the adaptive capabilities of energy systems of the athlete's body in order to further improve sportsmanship, expand functional reserves and maintain health is an urgent problem of long-term sports training. From the viewpoint of biochemistry, the most important factor determining it is the mobility, capacity, volume, and efficiency of both aerobic and anaerobic (alactic and lactic) energy supply mechanisms. (Hofman P. et al, 1994, Sybil M. H. et al, 2004, Pervachuk, R. V. et al, 2015, Drachuk S. P., 2005)

It follows that in order to improve physical qualities and, consequently, to increase sports results, it is necessary to improve both ways of energy productivity. It is known that purposeful improvement of aerobic and

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anaerobic components of energy supply can be carried out by means of various modes of physical training. (Kalinskii M.I. et al, 1986, Sybil M.G., 1996, Platonov V.N., 2004). However, the problem of improving both aerobic and anaerobic pathways of ATP resynthesis by exercising cannot be considered solved in water polo, especially for adolescents. Until now, the issue of regulation of physical activity depending on the functional readiness of the body and the issue of the most effective biochemical rapid control of this process remains controversial and insufficiently studied. (Astrand P.O., 1992, Sibil M. G., Ostrovskii M.V., 2005, Pervachuk, R. et al, 2016, Dennis C. et al, 1995, De Jesus K. et al, 2012, Cvjeticanin S. et al, 2012)

Cohort group – 16-year-old water polo players in the second phase of puberty. This is the most difficult period of human formation in general, and an athlete in particular. Since, on the one hand, sports activities promote physical development and the manifestation of physical qualities. On the other hand, constant physical activity is an additional burden on the body during puberty. Thus, biochemical control of adaptation to physical activity becomes especially relevant. (Poproshaev O. V., Polishchuk T. V., 2006, Mykola Chaplins'kyy et al, 2018) All these data are based mainly on scientific ideas about the age and the order of formation of different energy supply systems. (Korobeinikov G. V., Dudnik O.K., 2008, Mokhan R. et al, 2001) Various biochemical markers of response to physical activity have long been used to track the state of development of adaptive energy capabilities of athletes. Namely, creatinine, lactic acid, urea, inorganic phosphorus, etc. (Sybil M.H. et al, 2004).

Scientific sources do not sufficiently cover the question of the peculiarities of the impact of different training regimens on the aerobic and anaerobic performance of 16-year-old water polo players. Therefore, the problem of developing training programs, combined with a scheme of biochemical monitoring that would stimulate the development of both aerobic and anaerobic – alactic and lactic energy supply systems without harming the body of a young athlete. (Osipenko GA, 2007, Botonis, P. G. et al, 2019, 2021, Claus, G. M., 2017)

Materials and methods

Objective: Examination of the state of adaptation of energy systems of 16-year-old water polo players based on the indicators of biochemical monitoring under the influence of training physical activity on land and in water.

Task: To determine the content of energy indicators (lactic acid, inorganic phosphorus, urea) in the urine of water polo players before and after two hours of training and exercises in a pool.

Organization of the study.

15 water polo athletes aged 16 participated in the monitoring. Urine collection for lactic acid, inorganic phosphorus, and urea was performed 15-30 minutes before training and 15-30 minutes after training. In addition to training, which lasted two hours, a specialized load for this kind of sport was also used– a one-hour session in the pool.

Research methods.

Quantitative evaluation of inorganic phosphorus in urine by the Bell-Doisy-Briggs' method; Quantitative evaluation of urea content in urine by diacetylmonoxide method according to the test of "Lachema" company (Czech Republic); Quantitative evaluation of lactic acid excretion by Stromm's method.

Statistical processing of experimental data.

Statistical processing of the obtained experimental results was carried out using the application software package Excel. To compare the data about the content of energy indicators Student's *t*-test was used.

Research results and their discussion.

Lactic acid is a product of the glycolytic mechanism of ATP resynthesis in skeletal muscle, which is activated under conditions of intense exercise and in a hypoxic state of the body. After performing intensive work, the level of lactic acid in the blood increases, and its excretion in the urine also increases. When monitoring the effectiveness of the training process, it is advisable to determine the level of lactic acid excretion after performing standard physical activity. A decrease in the content of lactic acid in the blood and a decrease in its excretion in the urine from one stage of training to another indicates an increase in the level of training, and its increase – its ineffectiveness. If high concentrations of lactic acid in the blood are detected after performing the maximum work of submaximal capacity, it indicates a high level of training or increased metabolic capacity of glycolysis and greater stability of glycolytic enzymes. (Sybil M. H. et al, 2004)

Thus, the change in the concentration of lactic acid in the blood after exercise depends on the training level. Therefore, changes in its level in the blood and urinary excretion determine the degree of anaerobic training level of the body and the depth of fatigue in the areas of maximal and submaximal relative work capacity. (Kalinskii MI et al, 1986)

The results of the analysis of the level of lactic acid in the urine of athletes before and after training and training in the pool are presented in Fig. 1.

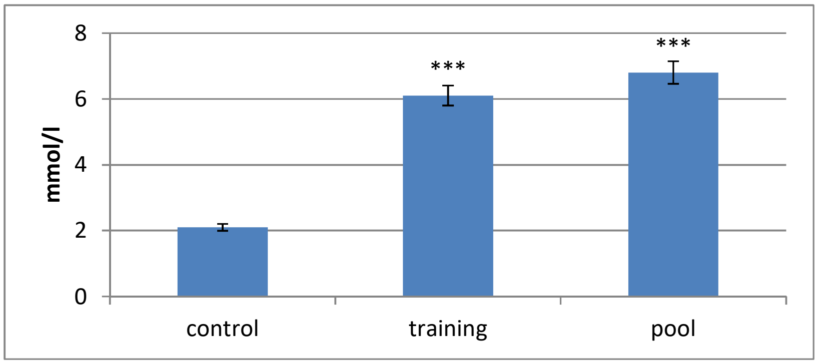

Fig.1 The level of lactic acid in the urine of water polo players at different types of loads (*** - p≤0.999)

After two hours of training, we observe that the amount of lactic acid in the urine increases by a factor of 3. This indicates the activation of the lactic anaerobic mechanism of athletes' energy supply. Training in the pool for one hour leads to an increase in the level of lactic acid in the urine of water polo players by 3.5 times. These results indicate a more significant activation of anaerobic glycolysis under conditions of training in conditions close to natural competitions of a playing format in water. The obtained data are reliable, the accuracy of the difference is p ≤ 0. 999 in both cases.

Phosphates play a major role in the formation of high-energy compounds - adenosine triphosphate and creatine phosphate, which are used as an energy source to support many physiological functions (muscle contraction, nerve cell function, membrane transport processes, etc.). Phosphates are part of phospholipids of cell membranes, phosphoproteins, nucleic acids, participate in the enzyme systems of the respiratory chain of mitochondria. Thus, phosphorus is included in the intermediate metabolism of proteins, fats, carbohydrates, oxygen metabolism, cell growth and division. (Sybil M. H. et al, 2004)

During physical activity, the excretion of inorganic phosphate in the urine increases. And the value of this increase correlates with the value of physical activity. Thus, inorganic phosphate under these circumstances mainly reflects the enhanced breakdown of ATP, which leads to an increase in its excretion in the urine. Therefore, in the practice of biochemical monitoring in sports, this indicator is used as an indirect biochemical marker of performed physical activity. (Sybil M.G., 1996)

The results of the analysis of the level of inorganic phosphate in the urine of athletes before and after training and training in the pool are presented in Fig. 2.

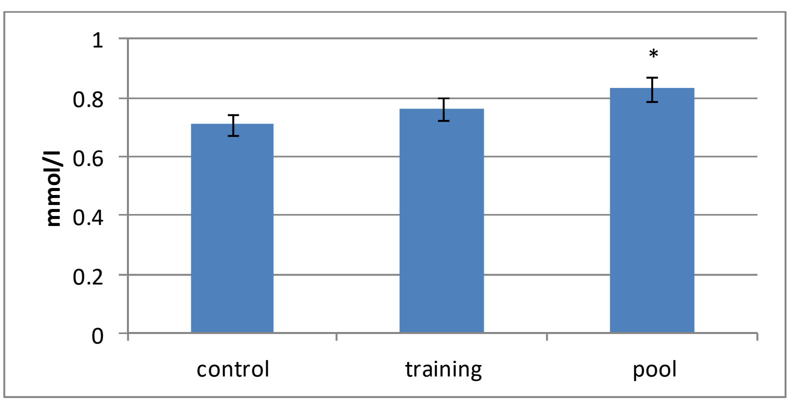

Fig.2 The level of inorganic phosphate in the urine of water polo players at different types of loads. (*-p≤0.95)

Inorganic phosphorus is as an indicator of general energy changes in the body, used by us to establish the difference between athletes' energy expenditure before and after exercise under the influence of two hours of training and exercises in the pool.

As it can be seen from Figure 2, training loads received during trainings do not lead to a significant increase in the level of inorganic phosphate in the urine of athletes. According to the average levels of inorganic phosphorus in the state before and after training on land, the data obtained almost do not differ, as evidenced by the calculated indicator of coefficient of Student's paired *t*-test ($p \geq 0.95$). Running competitions in the pool for an hour leads to an increase in the amount of inorganic phosphorus in the urine of water polo players, which is confirmed by the indicator of Student's paired *t*-test ($p \leq 0.95$). Namely, if the catabolism of ATP is replaced at the level of relative rest, it means that exercise stimulates its increased resynthesis during the training program. In our case, we can say about the sufficient level of physical training level of all energy systems of 16-year-old water polo players.

Urea characterizes the intensity of muscle protein breakdown and the level of amino acid deamination, resulting in the formation of toxic ammonia, which is converted in the liver into non-toxic urea. From the liver, urea enters the blood and is excreted in the urine. Subject to performance of long-term physical work due to increased protein catabolism, urea excretion increases. In the sequence of involvement of different sources of energy in energy metabolism, proteins occupy the last position. The body uses proteins as an energy source after depletion of carbohydrates and significant lipid catabolism.

Therefore, in the practice of biochemical monitoring in sports, this indicator is used to assess the athlete's undergone physical load. In other words, urea is a universal criterion to determine athlete's fatigue due to physical exercise. (Sybil M.G., 1996)

The results of the analysis of the urea level in the urine of athletes before and after training and training in the pool are presented in Fig. 3.

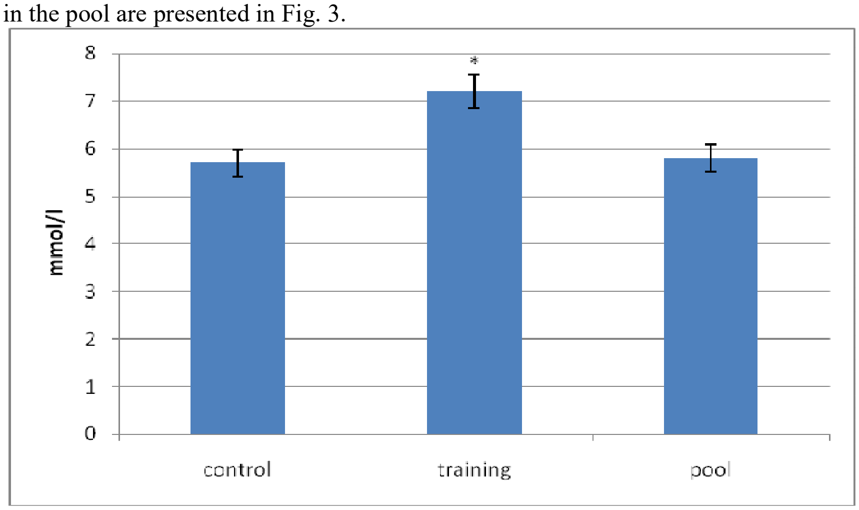

Fig. 3 The level of urea in the urine of athletes before and after training and training in the pool (* - $p \leq 0.95$).

The training of water polo players in the pool for an hour did not show changes in the urea level in the urine of water polo players. On average, both samples are almost identical, the comparative analysis did not reveal a significant difference ($p \geq 0.95$). Urea as an indicator of the aerobic path of the energy-supplied organism is used in observations of athletes as a criterion of stress-response of the body to exercise. The absence of changes in the level of this indicator before and after training in the pool proves that this type of training allows the athlete to avoid stress-response. This once again confirms the high level of fitness of athletes and their high qualification.

At the same time, physical activity received by athletes during a two-hour workout leads to a significant increase in the urea level in the urine of water polo players (* -$p \leq 0.95$). This indicates that an intensity of the training process stimulates the development of the aerobic component of the energy systems of the body of the water polo player.

Discussion.

As a result of the established statistically significant difference in the indicators of inorganic phosphorus, lactic acid and urea in the conditions of training on land and in the pool during the training of 16-year-old water polo players, the scheme of biochemical monitoring follows.

Namely, the fact of using lactic acid as a criterion for adaptation to anaerobic exercise is obvious. While urea is a product of protein catabolism, it is an indicator of the depth of the effect of training on aerobic metabolism, as proteins are included in energy metabolism due to exercise after carbohydrates and fats.

Inorganic phosphorus, as a product of ATP hydrolysis, is a biomarker of the cost of muscular effort, regardless of the path of ATP re-synthesis - anaerobic or aerobic.

Thus, as a result of biochemical monitoring of various training regimens (on land and in water) of 16-year-old water polo players, the following was established:

1. In terms of lactic acid, training regimens both on land and in water contribute to the development of anaerobic alactic component of energy supply, but to a greater extent within training in water.

2. In terms of urea in the urine, these exercises moderately contribute to the development of an aerobic energy supply mechanism, adequate to the second phase of puberty of young athletes (without stress response) and their intensity is higher during training on land.

3. In terms of inorganic phosphorus excretion, it is obvious that there is a balance between ATP catabolism and its resynthesis, which is inherent in mature athletes, and therefore training loads, both on land and in water, are adequate for 16-year-old water polo players.

Conclusion.

The proposed scheme of biochemical monitoring with the use of such biochemical markers as lactic acid and urea is an adequate reflection of the course of adaptation changes of 16-year-old athletes during their anaerobic and aerobic water polo training.

Biomarker of energy value of spent muscular effort – inorganic phosphorus is recommended for use as a component of biochemical monitoring of adaptation of energy systems in general in order to prevent exhaustion of the organism in the second phase of puberty.

This biochemical monitoring can be a model example of control over the adaptation of 16-year-old water polo players in the process of their training.

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