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Correction of Endurance Training and Competitive Activities of Athletes by Determining the Blood Urea Content

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Abstract

The generalization of data from the modern literature on the studied problem, as well as the results of previous studies by Stankevych, Zemtsova & Tomilova (2018), allowed to justify experimentally the choice of blood urea to correct one of the metabolic processes in training athletes. As a result of the study of athletes found that at the starting mesocycle of the special-preparatory stage of the preparatory period, the rate of blood urea in both groups of athletes did not differ significantly and amounted to 4.05±0.082 mmol·l^{-1} and 3.68±0.084 mmol·l^{-1} in women and 3.97±0.091 mmol·l^{-1} and 4.68±0.045 mmol·l^{-1} in men, accordingly. This content of blood urea corresponds to the average group norms and indicates the balance of anabolism and catabolism of proteins, and therefore, may indicate the state of recovery of athletes at the beginning of the mesocycle. However, the increase in this indicator at the end of the mesocycle indicates that the amount of training loads differs in the duration of work. However, both in athletic walking and in middle-distance runners, reliability was noted regarding the state of rest ($p<0.01$). Knowledge of the peculiarities of the functioning of this part of the metabolism and the development of ways to increase the effectiveness of this mechanism in terms of intense muscle activity should be considered as one of the promising research areas to improve training and competitive activities, as well as speed up recovery in athletes.

Keywords: *sport, endurance, metabolism, blood, blood urea*

Introduction

The formation of urea is closely related to various metabolic pathways: amino acid catabolism, gluconeogenesis, polyamine synthesis, transport of substances across the mitochondrial membrane. Thus, according to research (Litvinov, 1988), these connections indicate the existence of a complex system that affects the synthesis of urea in the body.

To date, thanks to fundamental research by domestic and foreign authors, the mechanisms of urea formation under different types of physical activity (Hecksteden et al., 2016) have been elucidated. It is established that the basis of urea formation during muscular activity is a violation of biochemical homeostasis and, first of all, a violation of the balance of adenosine triphosphate (ATP) in working muscles, as well as increased protein catabolism.

It is known that proteins are not the main source of energy during physical activity. Although their oxidation is less than 10% of total energy production, the results of numerous studies suggest that muscle work may not affect the breakdown of proteins, and cause strengthening or weakening of this process, depending on the conditions of exercise, and in particular, such as their different duration and intensity (Zemtsova et al., 2016), accompanied by changes in the concentration of amino acids in blood plasma. Muscle-stimulated protein

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breakdown in the liver can also cause the release of significant amounts of amino acids.

The actual breakdown of proteins should be determined by the dynamics of the concentration of essential amino acids, because the body does not synthesize them and any change in their content can be associated only with changes in plasma concentrations or endogenous breakdown.

Thus, according to some authors (Erkomajshvili & Seluyanov, 1990) found a significant increase in the concentration of essential amino acids such as tyrosine and leucine in skeletal muscle, liver and blood plasma in an experiment on rats after performing muscle work to failure. Similar data were obtained by Dohm, Kasperek and Tapscott (1987), who also found a progressive increase in plasma tyrosine content with increasing duration of muscle work.

Thus, according to Dunkin, Phillips and Strength (2017), a specific indicator of the degradation of contractile proteins is 3-methylhistidine (3-MG), because it is a secondary product of the breakdown of actin and myosin. In particular, it turned out that during muscle activity its content decreased, and in the recovery period - increased. It was found that the excretion of 3-MP does not increase in the recovery period after minor muscle tension but increases after exercise as their duration and intensity increase. A similar trend is observed with respect to the concentration of urea in blood plasma.

It is also established that the contribution of amino acids to the total energy supply during prolonged physical activity can range from 3 to 18% (Zemtsova et al., 2020).

During exercise that requires endurance, the breakdown of proteins occurs mainly in the liver and muscles, with the process of catabolism prevails over the process of protein synthesis. Thus, according to Viru (1981), the performance of work on the treadmill for one hour was accompanied by inhibition of protein synthesis in the liver by 20%, and when performing exercise to failure, this figure decreased by 65%. Therefore, the degree of inhibition of protein synthesis in the liver and skeletal muscle is determined by both the intensity and duration of exercise.

With high-intensity muscle activity, when ATP resynthesis occurs mainly due to respiratory phosphorylation, the elimination of ammonia is significantly enhanced, its content in the blood and tissues decreases, and the formation of urea - increases. This is confirmed by the fact that the increase in the concentration of blood urea is directly proportional to the duration of work with high intensity (Khmelnitskaya & Smyrnova, 2011). However, according to some studies by Kropta et al., (2020) low motor activity of 30% of oxygen consumption (VO_2max) does not cause significant changes in urea in the athlete.

The process of urea formation deserves special attention because it is known that proteins are a very dynamic component of skeletal muscles that produce ammonia, both during short-term intense and prolonged exercise of submaximal aerobic capacity. Thus, the determination of the dynamics of blood urea is used in the practice of biochemical control to determine the functional state of athletes at all stages of training (preparatory, competitive, transitional) to assess the impact of stress on the athlete, tolerance of training loads, total and anaerobic regimens in the process of muscle activity and the speed of recovery processes after exercise (Osipenko, & Vdovenko, 2017; Stankevich, & Zemtsova, 2014).

Determination of urea content in the blood allows to assess the functional and energy capabilities of runners (middle distances) and representatives of athletic walking by the level of metabolic changes and the functional response of the body to training and competitive loads of different energy orientation. The results of the study allow to correct individual training process.

The purpose of the study was to analyze the dynamics of blood urea concentration as an indicator of recovery processes in endurance athletes.

Methods

The study involved 28 athletes (15 men and 13 women) aged 19 to 30 years, with sports experience of 6 - 15 years (middle distance runners and representatives of athletic walking) qualifications of Master of Sports (MS) and International Master of Sports (ICMS). Written consent was obtained from each study participant. Athletes were at the special preparatory stage of the preparatory period of the annual training cycle. The concentration of blood urea was determined using a high-speed biochemical variophotometer "DiaglobalGmbH" (Germany) using ready-made reagents. Athletes performed test physical activity - overcoming distances of 15 km and 30 km. The results of the study were processed using mathematical statistics using standard computer programs.

Data were expressed as mean ± standard error of mean. Shapiro-Wilk test was used to analyze the normality of distribution. Paired t-test or two sample t-test was used to evaluate the difference in urea content. P values less than 0.05 were considered significant.

The study was conducted in accordance with the basic bioethical norms of the Helsinki Declaration of the World Medical Association on ethical principles of scientific and medical research, as amended (2000, as amended in 2008), the Universal Declaration on Bioethics and Human Rights (1997), the Council of Europe Convention on Human Rights and Biomedicine (1997). The study was approved by the NUUPES Biomedical Ethics commission, Kyiv, Ukraine (№2 16.12.2020). Written informed consent was obtained from each study participant.

Results

Biochemical assessment of the urgent and delayed training effect on the basis of determining a relatively small set of indicators provides information about the state of metabolic processes in the body, reveals the individual characteristics of metabolism in athletes.

Thus, to characterize the state of metabolism during rest after exercise, when there is a gradual normalization of metabolic processes and return to baseline, in the practice of sports is most used to determine the content of blood urea.

Determining the dynamics of urea concentration during intense muscular activity provides important information about the direction of metabolic processes occurring in the body during muscular activity, which, in turn, ensures compliance with all the rules of building a rational training process and justifies timely correction of training loads.

It is known that the body's response to exercise is expressed in three successive phases: exercise, recovery and supercompensation. Increased formation of urea during prolonged physical activity of high intensity and increase its content in the blood occurs in the late stages of physical activity.

To assess the special endurance of athletes who specialize in athletic walking, carried out a control test work - overcoming distances of 15 km and 30 km. They determined the content of blood urea at 2 hours, after 18 and 42 hours of recovery.

In addition, the content of blood urea of the studied athletes at rest at the beginning and end of the mesocycle of the preparatory period was determined.

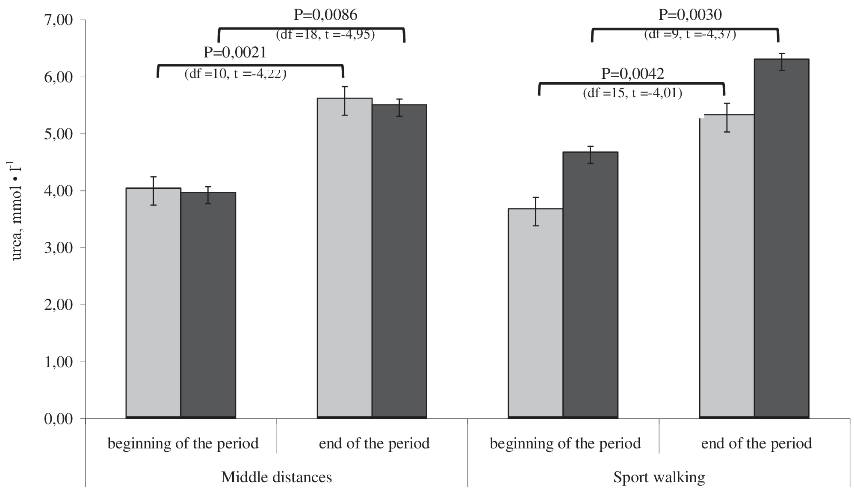
The studied endurance athletes (middle distance running and athletic walking) were at the special preparatory stage of the preparatory period.

The dynamics of the increase in blood urea of athletes has significant differences in the preparatory and competitive period. As a rule, the concentration of urea in the preparatory period is higher, which is due to the significant amount of training loads and low fitness of athletes.

For a more complete individual characterization of metabolic processes in the content of blood urea of athletes, we conducted a study as at the beginning, end of the mesocycle, as well as at different times of recovery after exercise.

As a result of the study of athletes (walking, middle distances) found (Figure 1) that at the beginning of the mesocycle of the preparatory period, the urea in both groups of athletes did not differ significantly and amounted to 4.05±0.082 mmol·l^{-1} and 3.68±0.084 mmol·l^{-1} in women and 3.97±0.091 mmol·l^{-1} and 4.68±0.045 mmol·l^{-1} in men, respectively. This blood urea content of both groups at the beginning of the mesocycle indicated a balance of anabolism and catabolism of proteins, and therefore may indicate the optimal state of the regenerative processes, the compliance of physical activity with the functional capabilities of the studied athletes.

However, the increase in this indicator at the end of the mesocycle (Figure 1) allows to guess that the amount of training loads was possibly different. Thus, in middle-distance runners (men), where the work is more intense, but much less over time, the increase in urea is much slower compared to representatives of athletic walking. However, both in athletic walking and in middle-distance runners, a significant difference was observed compared with the state of rest (p<0.01).

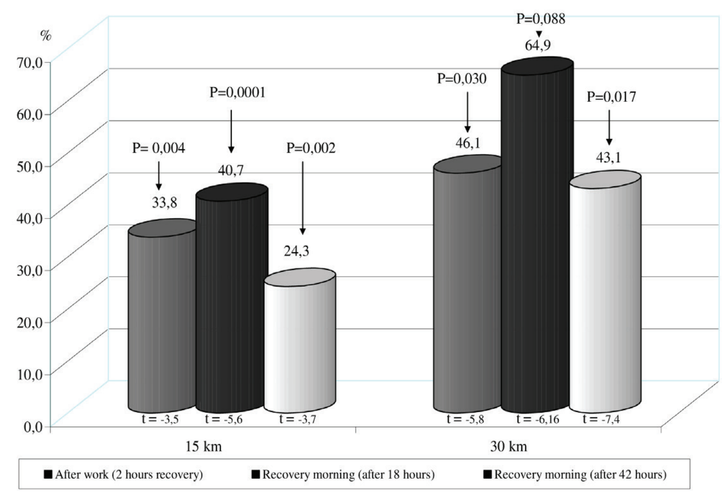


Legend: p - as calculated by paired t test

FIGURE 1. The content of blood urea in athletes trained for endurance at the beginning and end of the special training stage of the training period

Thus, significant amounts of training loads of the preparatory period enhance the breakdown of body proteins, which leads to the mobilization of protein resources of the body and there is an increased release of free amino acids from lymphoid and muscle tissues. These amino acids are reanimated in the liver in the necessary directions and are used for the synthesis of enzymes, which leads to an increase in energy resources and accelerate the development of structural changes in the body of athletes whose work is aimed at endurance.

Determination of blood urea after "shock" microcycles,



Legend: p - comparing with the state of rest (as calculated by t test)

FIGURE 2. Increment in the level of blood urea of representatives of walking after control-training loads comparing with a state of rest, in percent (15 km, 30 km)

which are characterized by significant volume and intensity at the special preparatory stage of the preparatory period, is an indicator of tolerability of individual training, microcycles and individual response of athletes to specific training loads of a particular microcycle.

To more fully characterize the state of recovery of athletes, we conducted a study of urea content at different times (in 2 hours, 18 hours and 42 hours) after control training, which consisted of overcoming distances of 15 km and 30 km (Figure 2). Thus, after the control and training load (15 km), the largest increase in blood urea was observed after 18 h of recovery and amounted to 40.7% relative to rest, and after 42 h there was a slight under-recovery, which amounted to 24.3% relative to rest.

After overcoming the control and training load (30 km), the content of blood urea increased significantly after two hours, which was 46.1% of rest, and at 18 hours of recovery, this figure was maximum and amounted to 64.9% of rest, after 42 hours, there was a gradual recovery of protein metabolism in athletes. This response to the load in the training period allows you to assess the response to specific training loads, their tolerability and get an idea of the functional state of the athlete in this period of training.

Discussion

Analysis of literature scientific data, as well as the results of our own research indicate that urea, as one of the end products of protein metabolism, really plays a significant role in the body's adaptation to intense muscular activity Dohm et al. (1987). At the heart of its biological effects are the features of the structure of the molecule, which determine its chemical properties, which are realized in the body in complex intersystem relationships.

In our opinion, the results of our study of the urea content in the blood of athletes at the beginning and end of the mesocycle of the special preparatory stage of the preparatory period of middle-distance runners and representatives of athletic walking deserve some attention.

So from the interpretation of the data to determine the level of blood urea during muscle activity deserves the fact that the concentration of this indicator may in some way reflect both the characteristics of energy supply processes and the amount of training work performed for one mesocycle.

The magnitude of the urea clearance itself varies depending on the volume and intensity of performed work: as a rule, it increases in the postpartum period. In studies by Viru (1981), strenuous muscle work delays the increase in the intensity of renal excretion of urea. Thus, during long-term work at the beginning of the recovery period (during the first six hours), its active accumulation in the blood continues, reaching the highest concentration. Inhibition of the functioning of the adrenal cortex, which is accompanied by changes in water-salt metabolism, causes a delay in blood urea.

Upon reaching the limit values of urea concentration, there was a lack of arginase activation, which plays an important role in the formation of urea Dunkin etc. (2017).

In studies by Stankevich and Zemtsova (2014), short-term recovery periods between frequent training loads were characterized by the maintenance of high-intensity protein catabolism and, accordingly, the level of blood urea. A significant increase in protein synthesis, according to Erkomajshvili and Seluyanov (1990) occurred only on rest days between microcycles, and the level of blood urea returns to its original state. It is known that the restoration of normal levels of blood urea occurred after a load of high power faster than after a long load of moderate power Dohm et al. (1987).

In the phase of supercompensation, along with various biological processes, the content of glycogen and protein in skeletal muscle increases, as a result of which the functional capabilities of the organism increase. This is the most important process of transition from urgent to long-term adaptation. The severity and duration of the supercompensation phase depends on the magnitude of the preload. At the same time, if during the period of incomplete processes of anabolism significant loads are used, then, on the contrary, the opposite state may appear - fatigue, overtraining. Since urea is an integral indicator of the course of recovery processes, the assessment of the dynamics of its concentration in the blood is one of the main indicators used in the practice of sports training. In most cases, to interpret the data obtained during biochemical control of blood urea, it is customary to focus on known types of reactions according to Erkomajshvili and Seluyanov (1990):

Type 1 is characterized by a direct correlation between the dynamics of urea and exercise, which indicates a balance of catabolic and anabolic processes, and also indicates that the loads used in the training process correspond to the range of functional capabilities of the body.

Type 2 manifests itself in a paradoxical decrease in urea, which is regarded as incomplete recovery processes, when conditions are created for inhibiting the formation of urea in connection with the active use of amino acids in the synthesis of skeletal muscle proteins.

Type 3 is characterized by the absence of any relationship between changes in the magnitude of the load and the urea content. At the same time increase of its level above individual norm within several days is noted. This type of reaction is observed after performing high-intensity long-term loads of a "stressful" nature and indicates a mismatch between the functional capabilities of the body and the training effects used, which serves as a signal to possible overstrain of functions and the body as a whole.

At a combination of inadequate increase or sharp decrease in concentration of urea in blood serum disturbance there can be a heart rhythm disturbance, decrease in the content of hemoglobin of blood below 120 $g{\cdot}l^{-1}$ at men and 100 $g{\cdot}l^{-1}$ at women, decrease in level of iron in blood and decrease in special working capacity (threshold speed and power), there is a failure of adaptation, which requires the use of a set of restorative and therapeutic measures.

The dynamics of recovery after significant training loads (overcoming distances of 15 km and 30 km) in the content of blood urea of athletes allowed to assess the state of training and readiness to perform such control and competitive loads. Training loads of microcycles caused a significant increase in the content of blood urea not after 2 hours, but in a later recovery period. However, the dynamics of the urea content was characteristic of the first type of reaction of urea to the load and by the beginning of the next microcycle the urea content decreased to baseline values. Based on the obtained data, we can conclude that the processes of recovery of metabolism in these athletes have been completed, do not require correction and correspond to the state of readiness for training.

Conclusions

The obtained data indicate that for effective control over the process of adaptation to physical activity in the process of training and control-competitive activities of middle-distance runners and representatives of athletic walking can be used to determine the content of blood urea.

Determining the content of blood urea after exercise makes it possible to assess the contribution of proteins to energy supply of muscular activity, and control of the dynamics of urea in the morning the next day after a set of training loads indicates the balance of anabolic and catabolic processes in the athlete. The definition of these indicators allows you to correct the training process quickly in order to increase its effectiveness.

Comprehensive use of this method makes it possible to control the processes of urgent and cumulative adaptation, to influence its course at the stage of specialized training of athletes and other sports with a similar nature of sports activities and energy supply.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

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