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ORIGINAL SCIENTIFIC PAPER

Biochemical Marker of the Monitoring of the Archer's Psychological Auto-Training

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Abstract

This study aimed to assess perfecting the archers' psychological readiness under different psychological conditions using biochemical methods of controlling urine metabolites. The athletes (5 archery masters and 11 candidates for sport masters; 19.87±0.24 years) random separated into two groups: a control (8 males, 19.87±0.29 years; according to the protocol) and an experimental user group (8 males, 19.87±0.39 years; in addition, used an auto-training technique). The subjects of the biochemical monitoring were lactate and urea in the isolated urine samples (pre- and post-training) during shooting training (Meeting) and official competitions (Competition). The use of 2 months of auto-training techniques by the experimental group archers significantly reduced the lactate concentration (9.7±0.4%; $p<0.05$) in the urine at the stage of official competitions, but not urea concentrations, compared to the control group. At the meeting stage, the utilization of the auto-training technique to contribute to changes in lactate excretion was insignificant, and at the Competition stage it was 21.4% ($p<0.05$). The auto-training technique does not significantly affect lactate and urea levels in the urine pre-training in both studied psychological states. However, as the psychological load increased at the Competition stage, the application of the auto-training technique led to a significant reduction in lactate concentration in the archers' urine compared to the control group. Unlike lactate, we cannot recommend urea as a marker for assessing the psychological state, but only as an indicator of the archers' fatigue.

Keywords: *lactate, urea, auto-training, archers, physical and psychological loadings*

Introduction

In the sports of martial arts, aerobic and anaerobic capacity (Sybil et al., 2015) and optimal tissue oxygenation (Levine, 2008) dominate in determining sports results and have an impact on the manifestation of varieties of athlete's endurance (general, including speed and strength endurance). The systematic training of an archer reflects a complex multistage process (Sarro et al., 2021; Vynogradskyi, 2012), which combines the processes of education, teaching, and training. An archer's effectiveness mostly depends on psychological preparation and the athlete's physical condition (balance and body posture; Sarro et al., 2021; Skala & Zemková, 2022), method of the conducting classes (Watson & Kleinert, 2019) and the individual approach of coach (Vynogradskyi, 2012; Watson & Kleinert, 2019). The decrease in productivity during physical loads is explained by the cumulative effect of fatigue, one of the factors of which is an accumulation of the metabolites in biological fluids (lactate and urea) and depletion of the energy substrates. Briskin, Pityn, Antonov, and Vaulin (2014) claim that psychological preparation is an innate feature, but it can be largely developed. Therefore, ideomotor training plays a special role in increasing the effectiveness of psychological stability (Vynogradskyi, 2012) and the performance of the archers (Briskin et al., 2014; Dolgova, 2017).

Lactic acid (lactate) is a normal product of human and mammalian metabolism, it is formed from pyruvic acid un-

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der physiological anaerobic conditions in the muscle tissues (Hall et al., 2016), brain (Li et al., 2023; Wu et al., 2023), skin (Mizukoshi et al., 2020) and small intestine (Ding & Xu, 2003). In case of violation/inhibition of oxidative phosphorylation, lactate gradually accumulates in the blood and is excreted in the urine. Another important major metabolite is urea, which is the final product of the protein catabolism in the body. This metabolite is synthesized in the ornithine cycle in the liver and is a pathway to eliminate a number of nitrogenous substances (harmful ammonia metabolites, for example) from the body (Wang et al., 2014).

Measurement of the lactate and urea concentration in the body fluids is known to be commonly used as a first step in the process of screening patients for clinical diagnosis and monitoring treatment in the following conditions: shock (≥4 mmol/L; Nichol et al., 2010); various types of sepsis and septic shock (Chertoff et al., 2015); systemic disease complications, including diabetes (Berhane et al., 2015; Brouwers et al., 2015), alcoholism (Zehtabchi et al., 2005), oncopathology (Apostolova & Pearce, 2022; Chetta et al., 2023), and liver dysfunction (Mizock, 2001); drug interference (Lalau, 2010); asphyxia in newborns (Tu et al., 2021); congenital metabolic disorders (Parikh et al., 2015); and pathologies of the heart and excretory systems, such as pyelonephritis, glomerulonephritis, and renal failure (Wang et al., 2014).

A completely distinctive picture of the accumulation of metabolites was established in the body fluids of athletes during physical and psychological loadings. The athlete's body switches to the reserve anaerobic pathway of energy synthesis when the generation of energy due to aerobic oxidation is impossible to perform high-power work (Sybil et al., 2015). With an increase in the specific gravity of the anaerobic process in the body, the concentration of lactate in the blood of athletes of the highest level in rowing, cycling, and taekwondo increases (Cubrilo et al., 2011), and urea in the archers' urine (Mahlovanyj et al., 2016). The concentrations of both metabolites increase in the blood plasma and sweat gland secretions of elite amateur rugby players (Alvear-Ordenes et al., 2005) have been established.

The biochemical characteristics of the various training loads revealed in the process of current control (during physical exertion and auto-training), allow for assessment of the degree of mobilization and use of the body's reserve capabilities, the direction and effectiveness of the training effect of the loads (Vynogradskyi, 2012). Changes in the concentration of lactic acid in tissues and biological fluids determine the anaerobic share of energy metabolism, and changes in urea determine the tolerance degree and endurance of athletes to various types of aerobic physical exertion (Boretskyi et al., 2022; Sybil et al., 2015). Determining the concentration of lactate and urea in the blood plasma is a traditional method of detecting pathological changes in the body. However, this classical method is invasive and therefore creates additional psychological loading for athletes and physical obstacles in the process of implementing tasks during preparation or improving results under competition conditions. Consequently, non-invasive monitoring of these metabolites, namely their excretion with urine, is an optimal method of biochemical monitoring of the psychological activity of archers.

A study has been conducted on the auto-training technique's influence on some mental qualities of shooters in bullet shooting (Moreira da Silva et al., 2021), the sports performance of athletes in air rifle shooting (Ihalainen et al., 2018) and pistol shooting (Sundaram et al., 2024). However, there is no information on the auto-training technique's influence on the accumulation of intermediate metabolites in the athletes' urine.

This study aimed to quantitatively assess the improvement of the psychological preparedness of archers under different psychological conditions using biochemical methods of controlling urine metabolites – lactate and urea. The importance of our research is to establish the characteristics of the lactate and urea accumulation in the archers' urine under various psychological and physical loading when using auto-training techniques during archery training and competitions.

Methods

Participants

Five archery masters and 11 candidates for sport masters (young men aged 19 to 22 years, M=19.8±0.24 years) participated in the experiment. To determine the effectiveness of the auto-training technique, athletes were randomly separated into two groups: experimental (2 archery masters and 6 candidates for sports masters; 19.87±0.29 years) and control (3 archery masters and 5 candidates for sports masters; 19.87±0.39 years), each of which consisted of 8 archers. Before each workout, the athletes of the experimental group used the proposed auto-training technique. The research lasted from September 2023 to March 2024 and took place in two stages.

Ethics

According to the bioethics rules, athletes gave written consent to participate in experimental research. Archery sportsmen also were obliged to be in good health, free of injury, symptomatic pain, and/or not on ongoing medication.

All studies were conducted in accordance with the Declaration of Helsinki guidelines. Approval for the study was taken from the ethics committee of Ivan Bobersky Lviv State University of Physical Culture (protocol No 2 from 25 May 2024).

Experimental treatment

The research was conducted based on the Department of Shooting and Technical Sports and the Department of Biochemistry and Hygiene (Ivan Bobersky Lviv State University of Physical Culture). The psychological-pedagogical experiment consisted of the introduction of an auto-training specialized technique for the psychological state regulation of the archers (Vynogradskyi, 2012); it was carried out for 2 months. The specialized technique of increasing the level of archers' psychological readiness (auto-training technique; session lasted 10-12 min per day) includes the attention concentration on each element of the technique and the nature of the athlete's emotional feeling during the execution of a bow shot (Vynogradskyi, 2012). The average number of ideomotor sessions was 5 or 6 per week, and the total duration per week was 50-60 min.

The auto-training technique application consisted of the fact that before each training, the archers-athletes first performed the calming part (in one of the positions: lying on their back, half-lying in a soft chair, or in the coachman position). After the first part of the auto-training, the archers moved on to the immobilizing part of the psycho-regulatory training. Then the athletes started shooting and before the real shooting (in a standing position) applied the third part of ideomotor training: the athlete closed his eyes and imagined the scheme of the correct shot. And only after ideomotor preparation and scrolling of the elements of the shot, a combat shot took place.

Measurements

Wang et al. (2014) studied that urine is an important body fluid that is easy to obtain noninvasively, it provides information for the diagnosis of various metabolic diseases. Biochemical examination of archers was carried out during two stages: during training (Meeting) and official competitions (Competition). Samples of biological fluid (urine) were taken before (pre-training) and after training (post-training). The concentration of lactate in urine was determined by Strom's color reaction (Barker & Summerson, 1941), and urea (Ormsby, 1942) by the spectrophotometric method according to the test of the company "Lachema" (Czech Republic).

Data analysis

The statistical analysis of the data, including the probability of differences in the determined indicators (Student's t-test) and the normality of distribution, was performed using the SPSS Statistics Base program (SPSS Inc., Chicago, IL, USA).

One-way ANOVA tests were conducted to compare the share of the contribution of the applied auto-training technique to the performance athletes (Glantz, 2012). The mean (M) and standard deviation (SD) were used to describe the data; p-values of ≤0.05 or lower were set as statistically significant.

To test the effect of the auto-training technique on the athletes' physiology, we evaluated the percentage of clinical changes of the indicators in the samples to determine suggestive values for the diagnosis of the metabolite levels and their changes in pre- and post-training according to the normal range of lactate (0.8÷1.2 mmol/L or 7.2÷10.8 mg/dl; Kamel et al., 2020) and urea (3.3÷5.8 mmol/L or 20÷35 mg/day; Laboratório Biomédico, [s.d.]; Phypers & Pierce, 2006).

Results

The level of lactate in the urine of archers during Meeting sessions before physical loading (pre-training) is on average 1.0÷1.2 mmol/L. After physical exercise implementation (post-training), the archers' urine samples showed a significant increase in lactate concentration in both groups (on average by 14.4±0.9%; Figure 1a). If we compare the lactate changes in the urine of athletes after physical activity (post-training), the experimental group found a significant increase in lactate concentration in urine by 14.5±0.8% compared to the control group of athletes, who did not use the auto-training technique (Figure 1a). The application of the psycho-regulatory training technique during the training sessions of archers did not affect the accumulation of an intermediate metabolite in the urine, which is due to the short-term use of the studied technique.

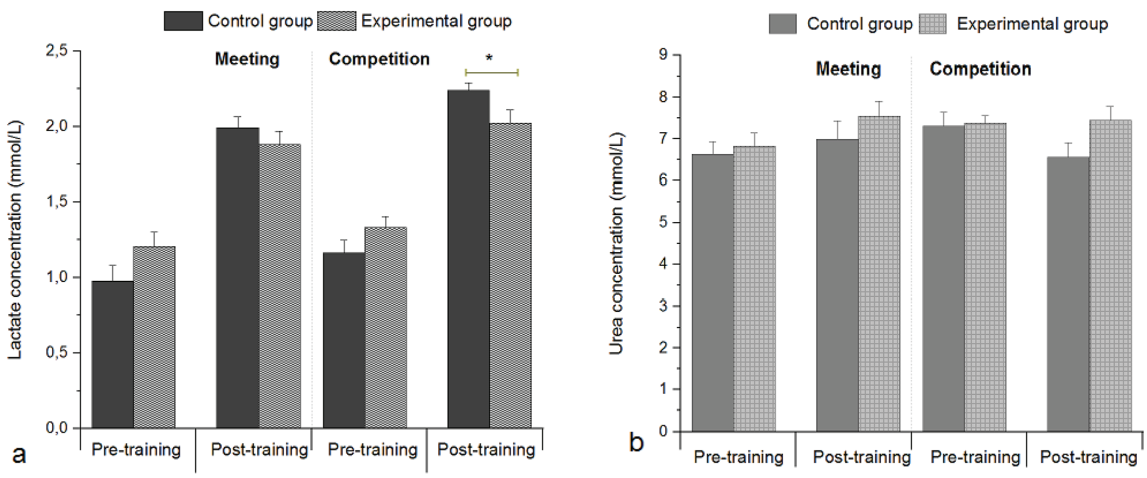

FIGURE 1. Comparison of the archers' urinary lactate (a) and urea (b) levels at the training session (Meeting) and official competition (Competition) (n=8): * – p≤0.05; statistically significant changes compared to the experimental group.

As shown in Figure 1a during official competitions the changes in lactate levels in the urine of archers pre-training also were similar. However, the long-term use of psycho-regulatory training techniques by archers in the experimental group led to a significant decrease of the lactate concentration by 9.7±0.4% ($p<0.05$) compared to the control group (Figure 1a).

The next stage of research was to analyze the level of urea in the urine of archers in pre- or post-training under different psychological states. As expected, urea levels increased after post-training in athletes in both groups, but no significant difference was found (Figure 1b). Under these conditions, no changes in the urea level of the athletes' experimental group were detected. This is primarily due to the type, diet, and level of protein consumption by athletes, as well as the level of training of the athletes' bodies. Because a trained organism is characterized by a higher efficiency of metabolism regulation, which is manifested by more economical energy expenditure during exercise (physical activity).

The level of lactate below the reference values was not found in both the control and experimental groups of athletes. At the same time, lactate values exceeded the upper limit of reference values in both groups at the Start stage (Figure 2a-b).

Lactate values exceed the normative values, while at the Meeting stage, the normal values decrease after physical activities, and at the Competition stage, the values exceed the reference values. Urea levels exceeded reference values both pre-and post-training at the researched stages (Figure 2c-d).

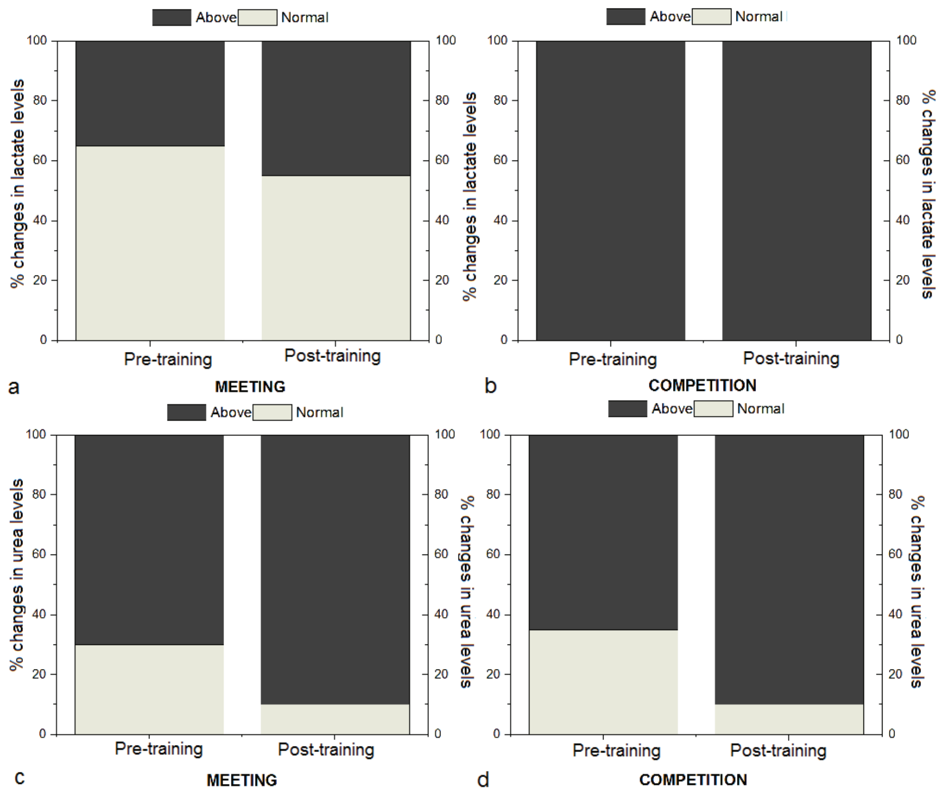

FIGURE 2. Percentage of clinical alteration in lactate (a–b) and urea (c–d) levels in the athletes in pre- or post-training conditions (classified as "normal" or "above" the normal range) at the different psychological states.

The results of the one-way ANOVA analysis of metabolite excretion in the archers' urine are shown in Figure 3. At the Meeting stage, an insignificant contribution of the influence of the auto-training technique on the archers' performance and lactate excretion was found (12.2%), while the share of influence of the other factors was 87.8%.

At the Competition stage, the contribution of using the auto-training technique to changes in lactate excretion was 21.4% ($p<0.05$). It should be noted that the contribution of unaccounted factors to the athletes' performance at the Meeting and Competition stages remained considerable (88.4%), but was insignificant.

The share of auto-training technique contribution to the performance athletes and urea excretion in the archers' urine (data not shown) was minimal (1.25±0.52%) and insignificant for both studied psychological and physical states.

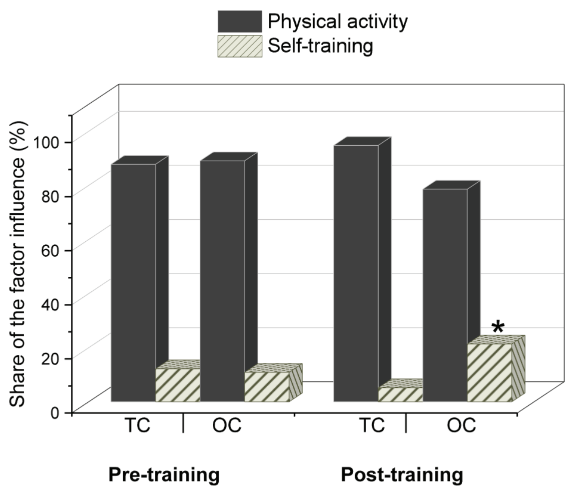

FIGURE 3. One-way ANOVA analysis of the changes of the urine archery lactate at the different psychological states (TC – training competition, OC – official competition) * – $p<0.05$.

Discussion

The findings of the current study indicate that the lactate and urea concentrations in the urine of archers during training and official competition, although tending to increase, but correspond to the reference values of these metabolites in healthy people without excessive physical exertion (Laboratório Biomédico, [s.d.]; Kamel et al., 2020; Phypers & Pierce, 2006). It is known that blood lactate values are significantly correlated at moderately elevated threshold concentrations with urinary lactate values (Hagen et al., 2000).

The lactic acid accumulation in the sportsman body's biological fluids reflects the transition from aerobic to anaerobic energy production systems (Boretskyi et al., 2022; Phypers & Pierce, 2006; Sybil et al., 2015). Monitoring this shift is an important parameter for adapting the training of athletes for endurance sports (Etxegarai et al., 2019). It is known that the concentration of the metabolites we studied in the blood increases rapidly during intense or continuous physical exercise by athletes (Saenko et al., 2015; Kistner et al., 2023). Kistner et al. (2023) proved that continuous intense exercise causes more profound changes in the urinary metabolites than continuous moderate exercise. This investigation demonstrated greater changes in the metabolites associated with glycolysis (e.g., lactate, pyruvate), with the tricarboxylic acid cycle and the breakdown of the purine nucleotides, as well as more intensive mobilization of the amino acids and their degradation (Kistner et al., 2023).

While archers do not generally use intense exercise during training sessions, their moderate training is aimed at controlling body balance, coordination of their movements, cognitive skills (Lu et al., 2021), and psychological/emotional state. Therefore, these trainings do not trigger maximum psychological loading on the archer's body during Meeting stage. In the Competition conditions, psychological endurance and focus play the most significant impact on the athlete's performance.

A study of the heart rate effect on shooting performance in elite archers showed (Açıkada et al., 2019) that in a simulated competition environment, high values of the cardiac cycle index at the threshold level of blood lactate in elite-level archers of different genders do not have a negative impact on indoor shooting performance (Açıkada et al., 2019). After performing physical exercises – running, which imitated a physiological standardized level of stress – the value of lactate in the blood of athletes was identified in the range of 1.3–7.0 mmol/L (in a relative rest state – 0.9–2.6 mmol/L).

The lactate accumulation in the muscles and ischemic tissues established lactate as a harmful waste product (Li et al., 2022; Pingitore et al., 2015). At the same time, providing cells of a healthy organism with both a convenient source and a sink of carbon compounds, lactic acid in the blood allows for the separation of mitochondrial energy generation from glycolysis. The duration of the recovery of various energy substrates in the body plays an important role in the correct construction of the training process and the restoration of the body's resources, both after physical and psychological loading. Lu Q. et al. (2021) concluded that auto-training technique should be considered as a useful addition to the daily training of athletes, including archers (Lu et al., 2021). The use of self-training techniques by archers is aimed at stabilizing and consolidating cognitive skills during high levels of psychological loading.

Systematic application of the proposed auto-training technique for 8 weeks significantly positively reduced the lactate concentration in the archer's urine and this directly correlates with improved archers' performance. Therefore, we can assume that the lactic acid level in the urine of athletes can be used as a marker for assessing psychological loading.

As expected (Laboratório Biomédico, [s.d.]; Saatkamp et al., 2016), a tendency to increase the level of urea was found both during psychological and physical loadings in athletes of both groups, however, these changes were not statistically confirmed. These changes in the urea level after applying the auto-training technique are primarily due to the type, diet, and level of protein consumption by athletes, as well as the level of fitness of the archers.

The metabolomics data of the urine of water polo players established changes in the metabolic characteristics (the level of glucose, lactic and succinic acids increased; Wang et al., 2021) immediately after official competitions compared to the results before the competitions. However, such changes in the athletes' metabolites are most likely associated with the use of active types of training exercises and a powerful load on active muscles during official water polo competitions.

Our results are consistent with the level of urea in archers during the assessment by Maglyovanyj and co-authors (2016) of the morpho-functional state of athletes for the scientific adjustment of their diet. The researchers determined the creatinine indicator in urine as a product of the creatine phosphokinase pathway of energy supply and a urea indicator in urine as an integral indicator of fatigue of athletes-archers (Mahlovanyj et al., 2016).

So, at the first stages of the application of specialized auto-training technique, the main factors that determine the performance of archers during training are the physical preparation and condition of the athlete. The long-term systematic application of this technique at the official competitions changed the contribution of the share of the effect of the auto-training technique application to changes in the excretion of an intermediate metabolite.

The results of the one-way ANOVA analysis of metabolite excretion in the archers' urine show that the contribution of the auto-training technique to changes in lactate concentration is the most significant and only occurs during maximal psychological load–specifically, during official competitions. During regular training, however, the lactate and urea levels in the urine of archers across different conditions are influenced primarily by physical activity or unaccounted factors specific to each group.

The practical results of shooting performance, along with our findings, suggest that biochemical markers in the archers' urine change after performing the auto-training technique, with these changes being statistically significant ($p<0.05$). Archers demonstrate varying levels of assimilation of the auto-training technique after two months of training, showing positive trends in shot execution. However, due to the small sample size of qualified archers, the results cannot be definitively generalized. It is recommended that this study be replicated with a larger number of participants and the inclusion of additional biochemical markers, such as creatinine and inorganic phosphate.

Conclusion

The use of the auto-training technique during the Meeting stage and in archers' official competitions did not affect the dynamics of urea accumulation in the urine, likely due to the lack of a direct connection between protein metabolism and the use of the studied technique. Unlike lactate, urea cannot be recommended as a marker for assessing psychological state, but rather should be considered only as an indicator of fatigue in archery athletes.

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Conflict of Interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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