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Metabolic responses in endurance horses at exhausted syndrome

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Contents

Abstract

The article shows the results of the study of biochemical blood indices in sports horses. It is shown that in horses after exercise developing the metabolic syndrome which is a result of insufficient supply of organs and tissues of energy accompanied by development of dehydration, cytolysis syndrome, uremic syndrome, electrolyte imbalance. Evaluation of cardiac output in horses must be performed during and after physical exertion, when during latent disease manifests itself clinically. It is important to know the ways of flowing the course of metabolic processes that occur in the body of horses during physical activity of varying intensity. The most common reason for excluding horses from sports events is metabolic disorders and cardiovascular dysfunction. The aim of the work was to investigate changes in biochemical blood parameters in sports horses after physical exertion. The material for research was horses, which are used in classical equestrian sports. In all horses the general analysis and biochemical parameters of blood, characterizing the functional state of the organs (heart, liver, kidneys) were investigated. The most frequent in horses for physical overstrain is registered increased fatigue, dyspnea, tachycardia, less frequent arrhythmias. In sports horses after exercise develops dehydration (hyperproteinemia), uremic syndrome (increasing the concentration of urea and creatinine), cytolysis syndrome (activity increase of AST and ALT), electrolyte imbalance (decrease in serum sodium and potassium). Hyperlactatemia that occurs in horses during exercise causes changes in the permeability of cardiomyocytes and exit enzymes in the blood and can play a key role in the pathogenesis of myocardial dystrophy. Installed tests can serve for early diagnosis of metabolic syndrome in horses for exercise.

Key words: horses, metabolic syndrome, myocardial dystrophy, hepatic and renal tests, blood lactate, electrolyte imbalance, exhausted syndrome.

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1. Introduction

The combination of the cardiovascular system diseases and metabolic disorders in the humane medicine has been known since the 1940s. In the 1980s, this combination was determined by the term of the metabolic syndrome, which was included in the group of metabolic risk factors that occur simultaneously in one patient. Nowadays the term “metabolic syndrome” is common in the medical literature, but there are minor devergence about diagnostic criteria (Poryadin and Oskolok, 2011).

The physical activity of horses requires energy for a long time (Treiber et al., 2006). Under such conditions, a stable energy requirement is accompanied by metabolic disorders, and that causes dysfunction of the cardiorespiratory, endocrine and neuromuscular systems (Flaminio and Rush, 1998; Schott et al., 2006).

The most common reason for excluding horses from sport competitions is colic (Fielding et al., 2009), while other researchers have found that the main cause is metabolic disorders and disfunction cardiovascular system (Trigo et al., 2010).

Active muscular activity promotes hypertrophy of the heart muscle. However, with the maximum muscular load, the increased use of adenosine triphosphate occurs, and the rate of supply with substrates and oxygen is insufficient. The reason for the development of myocardial dystrophy is the inconsistency between the energy expenditure in the functioning structures of the myocardium and their restoration, caused by significant increase in energy costs. According to the hypoxic theory, the pathological theory is caused by oxygen deficiency, and the neurodegenerative process connects myocardial dystrophy with the hypoxic effect of excess catecholamines (Kushakovsky, 2000).

However, due to physical activity, the electrolyte imbalance develops, as a result of which the processes of cellular respiration, oxidative phosphorylation and transmembrane exchange of cations are disturbed, which leads to a decrease in the formation of energy in the myocardium and the effectiveness of its use by functioning structures of the heart muscle (Tarmonova and Shutov, 2007). Due to energy deficiency the myocardial dystrophy develops, which is caused by metabolic disorders, which leads to the dystrophy and dysfunction of the heart muscle, accompanied by a disorder of electrical and metabolic processes in it (Dimopoulos et al., 2009). The development of electrophysiological and functional dysfunction of the myocardium is caused by cellular acidosis, local inflammation and peroxidation, violation of ionic equilibrium, decrease in the synthesis of adenosine triphosphate (Chernaya et al., 2010).

Evaluation of the horse's heart functional state must be done during and after activity, when the latent course of the disease manifests itself clinically. It is important to know the ways of the metabolic processes flow that occur in a horse body during physical activity of different intensity (Bergero et al., 2005).

The result of insufficient provision of physiological needs of tissues and organs during physical activities is a metabolic crisis, which can be manifested by fatigue, dehydration, oxidative or thermal stress (Trigo et al., 2010; Niedźwiedź et al., 2017).

During physical activity the parameters of homeostasis change in horses, in particular their biochemical blood profile (electrolytes and acid-base balance) (Castejon et al., 2006).

A number of studies have been conducted in to investigate changes in hematological parameters in horses' blood during physical activity (Piccione et al., 2003; Golovacha et al., 2017). However, studies concerning horses excluded from the competition because of the metabolic disorders due to physical exertion are not adequately covered (Fielding et al., 2009). Therefore, the *purpose* of our work was to investigate changes in biochemical blood parameters of sport horses after physical activities.

2. Materials and methods

50 horses were included into our research, used in the classic equestrian sport of Ukrainian warmblood horses (n = 20), Hanoverian (n = 15) and Westphalian (n = 15) breeds horses. Among the experimental animals there were 25 mares, 9 stallions and 16 geldings. The average age of horses was 8.4 ± 0.71 (3.5–16.0), weight – 479.4 ± 8.54 kg (350–605 kg).

The daily diet of horses included: meadow grass (6 kg), oats (6 kg), wheat bran (2 kg), three times per day. Salt and water were available without restrictions.

The horses were examined clinically: the internal body temperature was measured, the pulse and respiration rate were counted, the heart auscultation was performed, the color of the mucous membranes and the time of capillaries filling were determined.

For all horses, a general analysis and biochemical blood indices were analyzed, characterizing the functional state of the organs (heart, liver, kidneys). Mares were not enceinte. All horses were de-wormed and vaccinated, were in the same conditions of detention.

Studies were carried out immediately before physical activities and immediately afterwards. The duration of medium intensity of regular training was 1 hour: walk – 5 minutes; rising trot – 10 minutes; walk – 5 minutes; sitting trot – 10 min; walk – 10 minutes; gallop with transition to a walk – 10 min; walk – 10 min.

Blood samples of horses were taken from the jugular vein using injection needles Ø 16 × 40 mm into tubes (10 ml; Vacutest, Italy) without anticoagulant. The analysis of blood samples was carried out in the laboratory of the Department of Internal Animal Diseases and Clinical Diagnosis of Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies Lviv.

To obtain blood serum, the tubes were centrifuged at 3000 rpm for 10 minutes. The concentration of total protein, albumin, total bilirubin, glucose, urea, creatinine, total calcium, inorganic phosphorus, magnesium, activity of aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (AP) and gamma-glutamyl transpeptidase (GGT) in the serum were determined using an automatic biochemical analyzer Mindray BS-120 (China) with reagents PZ Cormay S.A. (Poland). The content of potassium and sodium in the horses' serum was determined on a semi-automatic biochemical analyzer BioChem SA (USA) using reagents High Technology Inc., Production RD Walpole (USA).

Mathematical analysis of the obtained results was carried out using software *Microsoft Office Excel* by means of conventional methods of variation statistics with estimation of the mean (M), its error (m), the probability by the Student's t-test.

3. Results and discussion

Most frequently increased fatigue, dyspnea, mild tachycardia (46.4 ± 1.20 beats per minute, 36–68 beats per minute) were observed in horses during physical activity, less frequently arrhythmias (sinus arrhythmia, supraventricular extrasystole).

The determination of total protein, albumin and globulin content allows determine the status (index) of body hydration, protein loss, or reduction of its synthesis (Rose and Hodgson, 1994). Studies of humans and dogs have shown that protein is not an important energy substrate during physical activity. For horses the role of protein during physical activity is unknown, but it is assumed that carbohydrates and fat oxidations predominate in energy supply (Pösö Reeta et al., 2004).

Serum total protein level horses of all breeds before physical activity was on the same level (table 1). After physical activity, the protein level increased in the blood of sport horses from three research groups, obviously, that is the result of dehydration. It was especially evident among horses of the Hanoverian ($P < 0.01$) and Westphalian ($P < 0.05$) breeds, while the horses of the Ukrainian warmblood horses had only a tendency of increasing (table 1). Significant dehydration observed in for horses that were excluded from the competition due to the metabolic crisis (Castejon et al., 2006; Francesca et al., 2007). After physical activity the content of albumin increased in blood of all research groups, but a significant difference was established only in the animals of the Hanoverian breed ($P < 0.05$; table 1).

The concentration of total bilirubin in serum of horses after physical activity increased. In horses of the Ukrainian warmblood horses – on 22%, the Hanoverian – 3.5% compared to the parameters before physical activity, and on 22.2% ($P < 0.05$) in the Westphalian breed (table 1). An increase in concentration of bilirubin in horses after physical activity may be the result of the development of cholestasis, which is obviously due to dyskinesia of the biliary tract during exercise (Golovacha et al., 2005), proved by the tendency to the increased level of AP and GGT in serum of all research groups (table 2).

The gamma glutamine transferase (GGT) is considered to be a marker of oxidative stress (Lee et al., 2004; Yang et al., 2007), which is a key in the development of metabolic imbalance (Lee and Jacobs, 2005; Fernando et al., 2009). The oxidative stress developed (Kinnunen et al., 2005; Demircan et al., 2009) in horses with a low training level during physical activity and an increased GGT serum level is the result of insufficient training of horses (Noleto et al., 2016).

Table 1
Biochemical parameters of blood serum sport horses before and after exercise

Breeds of horses	Groups	n =	Total protein, g/L	Albumins, g/L	Total bilirubin, µmol/L	Glucose, mmol/L	Urea, mmol/L	Creatinine, µmol/L
Ukrainian warmblood	Before exercise	20	61.3 ± 1.22	37.8 ± 0.78	24.1 ± 2.14	5.5 ± 0.22	5.3 ± 0.22	132.8 ± 5.42
	After exercise	20	63.8 ± 1.61	38.0 ± 0.56	29.4 ± 2.44	5.2 ± 0.21	6.2 ± 0.28*	162.3 ± 5.91**
Hanoverian	Before exercise	15	60.9 ± 0.95	36.2 ± 0.84	28.1 ± 1.76	5.5 ± 0.13	5.6 ± 0.16	127.7 ± 6.86
	After exercise	15	66.3 ± 1.34**	39.4 ± 0.68*	29.1 ± 1.81	5.3 ± 0.11	5.9 ± 0.28	145.4 ± 4.09*
Westphalian	Before exercise	15	61.2 ± 1.55	38.7 ± 0.96	26.6 ± 1.24	5.6 ± 0.15	5.1 ± 0.20	123.4 ± 3.88
		15	67.1 ± 2.07*	39.2 ± 0.44	32.5 ± 1.69*	5.2 ± 0.11*	5.6 ± 0.15*	165.2 ± 4.95***

Note: * – P < 0.05; ** – P < 0.01; *** – P < 0.001 (compared to exercises)

Table 2
Activity of enzymes of blood serum sport horses before and after exercise

Breeds of horses	Groups	n=	AST, U/L	ALT, U/L	AP, U/L	GGT, U/L
Ukrainian warmblood	Before exercise	20	257.2 ± 10.12	6.4 ± 0.54	112.2 ± 8.37	13.5 ± 0.90
	After exercise	20	300.0 ± 16.01*	7.3 ± 1.05	116.5 ± 9.69	14.2 ± 1.25
Hanoverian	Before exercise	15	257.2 ± 7.01	5.5 ± 0.34	111.3 ± 5.55	11.0 ± 0.73
	After exercise	15	292.9 ± 8.13***	6.5 ± 0.45	120.3 ± 6.60	12.2 ± 0.95
Westphalian	Before exercise	15	259.7 ± 11.27	5.2 ± 0.35	106.9 ± 5.01	12.8 ± 0.75
	After exercise	15	302.5 ± 6.89**	8.7 ± 0.95**	109.2 ± 7.60	13.8 ± 1.21

Note: * – P < 0.05; ** – P < 0.01; *** – P < 0.001 (compared to exercises)

Serum glucose concentration tended to decrease in all experimental groups of animals after physical activity (table 1). In horses of the Ukrainian warmblood horses, its blood concentration decreased on 5.4%, Hanoverian – by 3.6%. In horses of the Westphalian breed the blood glucose concentration was reduced by 7.1% ($P < 0.05$) after physical activity, compared to the values before the activity (table 1).

Determination of urea and creatinine blood concentration is used to assess glomerular filtration of the kidneys (Braun et al., 2003). For horses of the Hanoverian breed, the urea content tended to increase (by 5.4%), while in horses of the Ukrainian warmblood and Westphalian breeds it was increased significantly on 17.0% ($P < 0.05$) and 9.8% ($P < 0.05$; table 1).

The creatinine concentration in the blood of horses of three research groups increased after physical activity: horses of the Ukrainian warmblood horses on 22.2% ($P < 0.01$), Hanoverian – 13.9% ($P < 0.05$) and Westphalian breeds on 33.9% ($P < 0.001$; table 1).

Creatinine is a metabolite of creatin found in high concentrations in tissues that have a high energy demand, including skeletal muscles (98% of the total body creatin pool) (Rose and Hodgson, 1994; Sewell and Harris, 1995).

Physical activity causes an increase in the level of free oxygen radicals (Snaders, 1995) that have a vasoconstrictive effect, reduces the rate of glomerular filtration by direct inactivation of cyclooxygenase in epithelial cells (Ohtra et al., 2004). Physical activity also leads to an increase in the content of endothelin, catecholamines, angiotensin II, cytokines (Snaders, 1995) that release mediators, which promote the development of kidney ischemia (Sewell and Harris, 1995) and the development of acute renal failure (Hisanaga et al, 1999). So, in terms of physical activity, glomerular filtration of the kidneys is disturbed in horses, and the uremic syndrome develops.

According to the results of our study sport horses have significantly increased serum activity of AST after physical activity: Ukrainian ($P < 0.05$), Hanoverian ($P < 0.001$) and Westphalian ($P < 0.01$; table 2) breeds. Serum level of ALT also tended to increase after physical activity in horses of the Ukrainian warmblood and Hanoverian breeds (table 2), whereas in Westphalian horses the increase was significant (7.8%; $P < 0.01$).

The increased activity of AST and ALT in serum of horses is directly related to a violation of the permeability of the muscle cell membranes, it can be registered in case of myopathy during physical activity. However, the enzymes activity in the horses' blood depends on the level of physical preparation, intensity and duration of the load (Wanderley et al., 2015).

It is possible that the increase in activity of AST in the blood serum of horses after physical activity can be the result of a violation of the permeability of the membranes of cardiomyocytes due to damage to the myocardium (Singh et al., 2011).

Violation of the blood supply to the heart muscle leads to an imbalance between the supply of oxygen and the need for it in the myocardium and causes changes in the metabolism of cardiomyocytes. A limited amount of oxygen is distributed between the oxidation of glucose and free fatty acids, and the activity of both pathways of metabolism is reduced. In ischemia, glucose is cleaved mainly by anaerobic glycolysis, and the resulting pyruvate is not oxidizing decarboxylation, and is converted into lactate, which potentiates intracellular acidosis (Amosova, 2000; Lishnevskaja, 2008).

During exercise as a result of anaerobic glycolysis, muscle accumulates lactic acid, which causes a decrease in pH. One of the possible determinants of permeability changes in cardiomyocyte cells is the decrease in the synthesis of adenosine triphosphate (ATP), which is necessary to maintain the integrity of the membranes. It is shown that exercise results in ischemia and cellular acidosis, peroxidation and ion balance disturbances, which is the cause of the development of electrophysiological and functional myocardial dysfunction (Räsänen et al., 1996; Fernando et al., 2009).

According to the results of the research, it was found that concentration of lactate after exercise was likely to increase in horses Ukrainian warmblood ($P < 0.001$), Hanoverian ($P < 0.05$) and Westphalian ($P < 0.05$) breeds horses (Fig. 1).

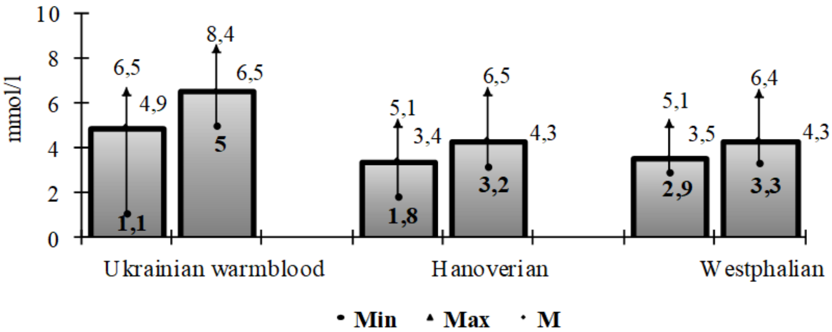

Fig. 1. The content of lactate in blood serum of sports horses before and after exercise

Increased lactate content is set in the blood of horses involved in eventing under after exercise (Andriichuk et al., 2014). One of the possible determinants of permeability changes in cardiomyocyte cells is the decrease in the synthesis of ATP, which is necessary to maintain the integrity of the membranes. During exercise due to anaerobic glycolysis in the blood accumulates lactic acid, which causes a decrease in pH (Fernando et al., 2009). Increasing the lactate that occurs in horses during exercise can play a key role in the pathogenesis of myocardial dystrophy in animals (Slivinska et al., 2018).

Our previous studies have established (Maksymovych, 2017) that the total calcium and inorganic phosphorus serum content in horses after a moderate-intensity activity tended to decrease. Physical activity of sport horses did not affect the exchange of magnesium in blood.

In sporting horses, after exercise the natrium blood serum content significantly decreases: in Ukrainian warmblood on 5.6% ($P < 0.05$), Hanoverian – 9.2% ($P < 0.01$) and Westphalian breeds on 13.3% ($P < 0.001$). The potassium serum content in the Hanoverian horses after the physical activity had the tendency to decrease (on 8.5%), whereas in the horses of the Ukrainian warmblood and Westphalian breeds the decrease was significant, respectively, on 10.5% ($P < 0.05$) and 19% ($P < 0.01$). Obviously that after physical activity, the reduction of sodium and potassium in serum of horses is due by the loss of electrolytes with sweat, which also causes the development of electrolyte disbalance (Maksymovych, 2017).

During activity in horses with metabolic imbalance, factors that are not related to feeding are more important. These include the loss of electrolytes with sweat, resulting in a violation of the neuromuscular transmission, and loss of water with sweat (dehydration) causes hemodynamic disturbances and impares supply of the oxygen and substrates, to the heart muscle (Lee and Jacobs, 2005). At the same time, the loss of water and electrolytes leads to the development of progressive metabolic alkalosis (Rose et al., 1979; McKeever, 2004; Piccione et al., 2008).

The results of our studies showed that an increase in the total protein content (dehydration), urea and creatinine (a violation of the functional state of the kidneys, which is characteristic of development uremic syndrome), a decrease in sodium and potassium levels (electrolyte imbalance), an increase in AST activity (cytolysis syndrome) can serve for early diagnosis of metabolic syndrome in horses during physical activity.

4. Conclusions

1. Horse's metabolic syndrome is the result of insufficient provision of organs and tissues with energy, accompanied by the development of dehydration, cytolysis, nephrotic syndrome, electrolyte imbalance.

2. Sport horses, have dehydration (hyperproteinemia), uremic syndrome (increased urea and creatinine concentration), cytolysis syndrome (increased activity of AST and ALT) after physical activity.

3. The concentration of lactate increases in the blood after exercise of sports horses of the Ukrainian warmblood, Hanoverian and Westphalian breeds.

4. The serum levels of sodium and potassium in horses decrease after physical activity due to the loss of electrolytes with sweat and the development of electrolyte imbalance.

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