ISSN : 2321-9602

Indo-American Journal of Agricultural and Veterinary Sciences




editor@iajavs.com
iajavs.editor@gmail.com

Indo-American Journal of Agricultural and Veterinary Sciences

ISSN 2321–9602 www.iajavs.com

The effects of fatigue on endurance horses' metabolism

Saradhi M[1] , Deepak A[2]

Abstract

Research on the biochemical blood indicators of performance horses is presented here. Dehydration, cytolysis syndrome, uremic syndrome, and electro- lyte imbalance are all symptoms of the metabolic syndrome, which develops in horses after exercise due to an inadequate supply of energy to the organs and tissues. Horses' cardiac output should be measured before, during, and after exercise since that's when dormant diseases first show themselves clinically. Understanding how the metabolic processes in a horse's body change in response to different levels of physical exertion is crucial. Metabolic problems and cardiovascular dysfunction are the leading causes of exclusion from competition for horses. The study set out to examine post-exercise alterations in biochemical blood markers in performance-oriented horses. Research subjects were horses, which are used in the equestrian disciplines. The general analysis and biochemical characteristics of blood were studied in all horses to characterize the functional status of the organs (heart, liver, and kidneys). Overexertion manifests itself most often in horses as increased weariness, dyspnea, tachycardia, and less often arrhythmias. Dehydration (hyperproteinemia), uremic syndrome (increased concentration of urea and creatinine), cytolysis syndrome (increased activity of AST and ALT), and electrolyte imbalance (decreased serum sodium and potassium) all manifest themselves in exercise-induced muscle damage in performance horses. Changes in the permeability of cardiomyocytes and exit enzymes in the circulation are caused by the hyper- lactatemia that occurs in horses during exercise and may play a crucial role in the pathophysiology of myocardial dystrophy. Pre-exercise metabolic syndrome in horses may be detected with the use of installed tests.

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

1. Introduction

Since the 1940s, practitioners of humane medicine have been aware of the correlation between illnesses of the circulatory system and metabolic problems. The term "metabolic syndrome," which refers to a cluster of risk factors for metabolic disease, was used in the 1980s to describe this constellation. Despite the widespread use of the term "metabolic syndrome" in modern medical writing, there is still some disagreement among experts concerning its precise diagnostic criteria (Poryadin & Oskolok, 2011).

Horses have a high energy demand due to their prolonged physical activity (Treiber et al., 2006). When this happens, the cardiorespiratory, endocrine, and musculoskeletal systems all break down despite a constant energy demand (Flaminio and Rush, 1998; Schott et al., 2006).

Fielding et al. (2009) reported that colic was the leading cause of exclusion from competition for horses used in sports, whereas Trigo et al. (2010) found that metabolic diseases and circulatory system dysfunction were the primary causes.

Heart muscle hypertrophy is facilitated by active muscular activity. With maximal muscular load, however, there is an increase in adenosine triphosphate consumption and an inadequate rate of substrate and oxygen delivery. Myocardial dystrophy arises when there is a discrepancy between the amount of energy utilized by the myocardium's functional components and the amount of energy necessary to restore them. Myocardial dystrophy, a neurodegenerative condition, is linked to the hypoxic impact of excess catecholamines, according to the hypoxia hypothesis (Kushakovsky, 2000).

Electrolyte imbalance, brought on by exercise, disrupts cellular respiration, oxidative phosphorylation, and transmembrane cation exchange, reducing energy production in the myocardium and the efficiency with which it is used by the heart's contracting structures (Tarmonova & Shutov, 2007). Myocardial dystrophy is a condition of the heart muscle that results from a lack of energy and is caused by metabolic problems that disrupt the heart's electrical and metabolic functions (Dimopoulos et al., 2009). Cellular acidosis, local inflammation and peroxidation, violation of ionic balance, and a reduction in adenosine triphosphate synthesis are all factors in the onset of electrophysiological and functional dysfunction of the myocardium (Chernaya et al., 2010).

1. Assistant professor, Department of Pharmaceutical Analysis, Sri Venkateswara College of Pharmacy, Vijayawada .
2. Assistant professor, Department of Pharmacology, Sri Venkateswara College of pharmacy, Vijayawada ..

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, dehy- dration, 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 pro- file (electrolytes and acid-base balance) (Castejon et al.,2006).

A number of studies have been conducted in to investi- gate 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 inves- tigate 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 ac- tivities and immediately afterwards. The duration of medi- um intensity of regular training was 1 hour: walk –5 minutes; rising trot – 10 minutes; walk – 5 minutes; sittingtrot – 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 Diag- nosis 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 cal- cium, inorganic phosphorus, magnesium, activity of aspar- tate 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 ofpotassium 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 con- ventional 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 tachy- cardia (46.4 ± 1.20 beats per minute, 36–68 beats per mi- nute) 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 hydra- tion, 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 phys- ical activity is unknown, but it is assumed that carbohy- drates 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 phys- ical 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 hors- es 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 de- hydration 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 ani- mals 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% com- pared to the parameters before physical activity, and on22.2% ($P < 0.05$) in the Westphalian breed (table 1). An increase in concentration of bilirubin in horses after physicalactivity 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

Indo-American Journal of Agricultural and Veterinary Sciences
ISSN 2321–9602 www.iajavs.com

developed (Kinnunen et al., 2005; Demircan et al., 2009) in horses with a low training level during physical activity and an increased GGT serum levelis 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 =	l protein,g/L	ɔumins,g/L	al bilirubin, µmol/L	Glucose, mmol/L	Urea, mmol/L	reatinine, 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**
	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
Hanoverian	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*
		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
Westphalian	Before exercise							
		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, itsblood concentration decreased on 5.4%, Hanoverian – by3.6%. 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 in- creased 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: hors- es 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 con- centrations in tissues that have a high energy demand, in- cluding 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, cyto- kines (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 ure- mic 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 forit in the myocardium and causes changes in the metabolism of cardiomyocytes. A limited amount of oxygen is distribut- ed between the oxidation of glucose and free fatty acids, andthe 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, mus- cle 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 aden- osine 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 bal- ance 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).

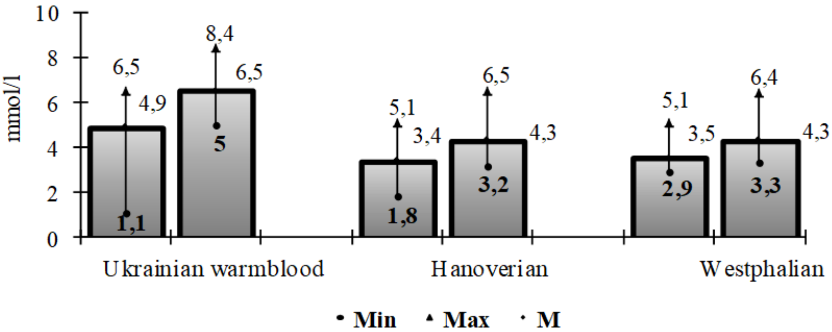

Fig. 1. The content of lactate in blood serum of sports horses before and after exercise Increased lactate content is set in the blood of horses in- volved in eventing under after exercise (Andriichuk et al., 2014). One of the possible determinants of permeability changes in cardiomyocyte cells is the decrease in the synthe-sis 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 de- crease 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 (Sliv- inska 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 se- rum content significantly decreases: in Ukrainian warm- blood 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 physicalactivity, 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, fac- tors 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 ofwater with sweat (dehydration) causes hemodynamic dis- turbances and impares supply of the oxygen and substrates, to the heart muscle (Lee and Jacobs, 2005). At the sametime, the loss of water and electrolytes leads to the devel- opment 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.

Indo-American Journal of Agricultural and Veterinary Sciences
ISSN 2321–9602 www.iajavs.com

4. Conclusions

1. Horse's metabolic syndrome is the result of insuffi- cient provision of organs and tissues with energy, accompa- nied by the development of dehydration, cytolysis, nephrotic syndrome, electrolyte imbalance.
2. Sport horses, have dehydration (hyperproteinemia), uremic syndrome (increased urea and creatinine concentra- tion), cytolysis syndrome (increased activity of AST and ALT) after physical activity.
3. The concentration of lactate increases in the blood af- ter 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 electrolyteswith sweat and the development of electrolyte imbalance.

References

Bergero, D., Assenza, A., & Caola, G. (2005). Contribution to our knowledge of the physiology and metabolism of endurancehorses. *Livest. Prod. Sci.,* 92(2), 167–176. doi: 10.1016/j.livprodsci.2004.11.019.

Braun, J.P., Lefebvre, H.P., & Watson, A.D.J. (2003). Creatinine in thedog: a review. *Vet. Clin. Pathol.,* 32(4), 162–179. https://www.ncbi.nlm.nih.gov/pubmed/14655101.

Castejon, F., Trigo, P., Muñoz, A., & Riber, C. (2006). Uric acid responses to endurance racing and relationships with performance, plasma biochemistry and metabolic alterations. *Equine Vet. J.,* 36, 70–73. doi: 10.1111/j.2042-3306.2006.tb05516.x.

Chernaya, M.A., Dementieva, I.I., Morozov, Yu.A., & Gladysheva,
V.G. (2010). Cardiospecific biomarkers in cardiology and car- diosurgery. Part 1. General characteristics of biomarkers. *Car- diology and cardiovascular surgery*, 3, 26–33 (in Russian).

Demircan, S., Yazici, M., Durna, K., Kilicaslan, F., Demir, S., Pinar, M., & Gulel, O. (2009). The importance of gamma- glutamyltransferase activity in patients with coronary artery disease. *Clin. Cardiol.,* 32(4), 220–225. doi: 10.1002/clc.20345.

Dimopoulos, K., Diller, G.P., Giannakoulas, G., Petraco, R., Chamaidi, A., Karaoli, E., Mullen, M., Swan, L., Piepoli, M.F.,Poole-Wilson, P.A., Francis, D.P., & Gatzoulis, M.A. (2009). Anemia in adults with congenital heart disease relates to adverse outcome. *J. Am. Coll. Cardiol.,* 54(22), 2093–2100. doi: 10.1016/j.jacc.2009.06.050.

Fernando, J.G., Claudio, C.Z., Leonardo, R.S., Lucia, P.S., & Denise, V.M. (2009). Possible relationship between perfor- mance and oxidative stress in endurance horses. *J. Equine Vet. Sci.,* 29(4), 206–212. doi: 10.1016/j.jevs.2009.02.006.

Fielding, C.L., Magdesian, K.G., Rhodes, D.M., Meier, C.A., & Higgins, J.C. (2009). Clinical and biochemical abnormalities in endurance horses eliminated from competition for medical complications and requiring emergency medical treatment: 30 cases (2005–2006). *J. Vet. Emerg. Crit. Care,* 19(5), 473–478. doi: 10.1111/j.1476-4431.2009.00441.x.

Flaminio, M.J., & Rush, B.R. (1998). Fluid and electrolyte balance in endurance horses. *Vet Clin. N. Am.: Equine Pract.,* 14(1), 147–158. doi: 10.1016/S0749-0739(17)30217-1.

Francesca, S., Harold, C.S., Kenneth, W.H., Raymond, J.G., & Eduard, J.C. (2007). Electrolyte supplementation for endurance horses: effects of fluid losses and performance. *AAEPProc,* 42, 82–85. http://www.karenchaton.com/wp-content/uploads/ 2008/09/electrolytes_endurance_horses.pdf.

Golovacha, V.I., Piddubnyak, A.V., & Chub, O.V. (2017). Eryth- rocytopoesis indexes in mares of the Ukrainian up-rider breed before and after parturition. *Scientific notes UO VGAVM,* 53(2), 119–123 (in Russian).

Golovacha, V.I., Ushkalov, V.O., Zhyla, I.A., Kutsan, O.T., & Bobrovska, N.V. (2005). Diagnosis and correction of hepato- renal syndrome in horses with gastric fodder toxicosis. *Bulletinof the Bila Tserkva State Agrarian University*, 33, 19–30 (in Ukrainian).

Hisanaga, S., Ueno, N., Inagaki, H., Tokura T., Uezono, S., Yoko- ta, N., Fujimoto S., & Eto, T. (1999). Exercise-induced acute renal failure associated with renal vasoconstriction. *Nippon Jinzo Gakki Shi.,* 41, 406–412. https://www.ncbi.nlm.nih.gov/pubmed/10441990.

Kinnunen, S., Atalay, M., Hyyppa, S., Lehmuskero, A., Hanninen, O., & Oksala, N. (2005). Effects of prolonged exercise on oxidative stress and antioxidant defense in endurance horse. *J. Sports Sci. Med.,* 4, 415–421. https://www.ncbi.nlm.nih.gov/ pmc/articles/PMC3899657.

Kushakovsky, M.S. (2000). Metabolic diseases of the heart (Myo- cardia – myocardosis – myocardial dystrophy – cardiomyopa- thy). St. P.: Foliant (in Russian).

Lee, D.H., Blomhoff, R., & Jacobs, D.R. (2004). Is serum gamma glutamyltransferase a marker of oxidative stress? *Free Radic. Res.,* 38, 535–539. https://www.ncbi.nlm.nih.gov/pubmed/15346644.

Lee, D.H., & Jacobs, D.R. (2005). Association between serum gam- ma glutamyltransferase and C-reactive protein. *Atherossclerosis,* 178, 327–330. doi: 10.1016/j.atherosclerosis.2004.08.027.

Maksymovych, I.A. (2017). Exchange of electrolytes in sports horse for exercise. *Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies named after S.Z. Gzhytskyj,* 19(77), 100–104. doi: 10.15421/nvlvet7723 (in Ukrainian).

McKeever, K.N. (2004). Body fluids and electrolytes: responses to exercise and training. Equine Sports Medicine and Surgery. *Basic and Clinical Sciences of the Equine Athlete,* 2004, 854– 871. doi: 10.1016/B978-0-7020-2671-3.50042-8.

Niedźwiedź, A., Maksymovych, I., Slivinska, L., & Kubiak, K. (2017). Metabolic syndrome in horses. *Scientific notes UO VGAVM*, 2017, 53(2), 106–110 (in Russian).

Ohtra, T., Sakano, T., Igarashi, T., Itami, N., & Ogawa, T. (2004). Exercise-induced acute renal failure associated with renal hypouricaemia: Results of a questionnaire-based survery in Ja- pan. *Nephrol. Dial. Transplant.*, 19(6), 1447–1453. doi: 10.1093/ndt/gfh094.

Noleto, P.G., Cubas, J.P.C., Barbosa, F.C., Guimarães, E.C., & Mundim, A.V. (2016). Biochemical profile of polo horses in training phase and those players of official competition. *Comp. Clin. Pathol.*, 25, 911–915. doi: 10.1007/s00580-016-2281-6.

Piccione, G., Arcigli, A., Costa, A., Percipalle, M., & Caola, G. (2003). Acid-base balance assessment during exercise in the show jumping horse. *Folia Vet.*, 47(2), 91–94.

Piccione, G., Vazzana, I., Giannetto, G., Gianesella, M., & Fer- rantelli, V. (2008). Modification of some hematological and hematochemical parameters in horse during long distance rides. *Res. J. Vet. Sci.*, 1(1), 37–43. doi: 10.3923/rjvs.2008.37.43.

Poryadin, G.V., & Oskolok, L.N. (2011). Pathophysiological as- pects of the metabolic syndrome. *Therapeutics*, 4, 1–10 (in Russian).

Pösö Reeta, A., Hyyppa, S., & Geor, R.J. (2004). Metabolic re- sponses to exercise and training. In: Equine sports medicine and surgery. Hinchcliff K.W., Kaneps A., Geor R.J. (Eds.), Saunders, China, 771–792.

Rose, R.J., & Hodgson, D.R. (1994). Hematology and biochemis- try. In: Principles and practice of equine sports medicine: The athletic horse. Hodgson D.H., Rose R.J., Saunders W.B. (Eds.), Company, Philadelphia, 63–78.

Rose, R.J., Ilkiw, J.E., & Martin, C. (1979). Blood-gas, acis-base and haematological values in horses during an endurance ride. *Equine Vet. J.*, 11, 56–59. https://www.ncbi.nlm.nih.gov/pubmed/34511.

Schott, H.C., Marlin, D.J., Geor, R.J., Holbrook, T.C., Deaton,C.M., Vincent, T., Dacre, K., Schroter, R.C., Jose-Cunilleras, E., & Cornelisse, C.J. (2006). Changes in selected physiological and laboratory measurements in elite horses competing in a 160 km endurance ride. *Equine Vet. J.*, 36, 37– 42. doi: 10.1111/j.2042-3306.2006.tb05510.x.

Sewell, D.A., & Harris, R.C. (1995). Effects of creatinine supple- mentation in the Thoroughbred horse. *Equine Vet. J. Suppl.*, 18, 239–242. doi: 10.1111/j.2042-3306.1995.tb04928.x.

Singh, T.P., Nigam, A.K., Gupta, A.K., & Singh, B. (2011). Cardi- ac Biomarkers: When to Test? – Physician Perspective. *JIACM*, 2011, 12(2), 117–121. http://medind.nic.in/jac/t11/i2/jact11i2p117.pdf.

Snaders, L.R. (1995). Exercise-induced acute renal failure associ- ated with ibuprofen, hydrocholorothiazide and triamterene. *J. Am. Soc. Nephrol.*, 5(12), 2020–2023. https://www.ncbi.nlm.nih.gov/pubmed/7579049.

Tarmonova, L.Yu., & Shutov, A.M. (2007). Anemia and renaldysfunction in elderly and senile patients with diastolic heart failure. *Clinical gerontology*, 13(11), 8–12 (in Russian).

Treiber, K.H., Hess, T.M., Kronfeld, D.S., Boston, R.C., Geor, R.J.,Friere, M., Silva, A.M., & Harris, P.A. (2006). Glucose dynam-ics during exercise: dietary energy sources affect minimal modelparameters in trained Arabian geldings during endurance exer- cise. *Equine Vet. J.*, 36, 631–636. doi: 10.1111/j.2042-3306.2006.tb05617.x.

Trigo, P., Castejon, F., Riber, C., & Muñoz, A. (2010). Use of biochemical parameters to predict metabolic elimination in endurance rides. *Equine Vet. J.*, 42(38), 142–146. doi: 10.1111/j.2042-3306.2010.00238.x.Wanderley, E.K., Bem, B.C.S., Melo, S.K.M., Gonzales, J.C., Manso, H.E.C.C., & Manso Filho, H.C. (2015). Hematological and biochemical changers in Mangalarga Marchador horses af- ter a hour-beat gait challenge in three different distances. *J. Equine Vet. Sci.*, 35, 259–263. doi: 10.1016/j.jevs.2015.01.009.

Yang, H.K., Hong, K.M., Seck, M.S., Kim, I.J., & Yong, K.K. (2007). The association of serum gamma glutamyltransferase with components of the metabolic syndrome in the Korean adults. *Diabetes Res. Clin. Pract.*, 77, 306–313. doi: 10.1016/j.diabres.2006.11.009.

Amosova, E.N. (2000). Metabolicheskaja terapija povrezhdenija miokarda, obuslovlennogo ishemiej: novyj podhod k lecheniju ishemicheskoj bolezni serdca i serdechnoj nedostatochnosti. *Ukr. kardiol. zhurn.*, 4, 85–92 (in Ukrainian).

Lishnevskaja, V.Ju. (2008). Metabolicheskaja terapija pri IBS – iz proshlogo v budushhee. *Consilium Medicum Ukraina*, 1, 34–39(in Russian).

Fernando, J.G., Claudio, C.Z., Leonardo Dos, R.S., Lucia, P.S., & Denise, V.M. (2009). Possible relationship between performance and oxidative stress in endurance horses. *J. Equine Vet. Sci.*, 29(4), 206–212. doi: 10.1016/j.jevs.2009.02.006.

Räsänen, L.A., Wiitanen, P.A., Lilius, E.M., Hyyppa, S., & Poso,
A.R. (1996). Accumulation of uric acid in plasma after repeated bouts of exercise in the horse. *Comp. Biochem. Physiol. B. Biochem. Mol. Biol.,* 114(2), 139–144.
https://www.ncbi.nlm.nih.gov/pubmed/8759288.

Andriichuk, A.V., Tkachenko, H.M., Kurhaliuk, N.M., Tkachova, I.V., & Vartovnyk, M.S. (2014). Zminy metabolichnykh reak- tsii v krovi trybornykh konei v dynamitsi treninhu. *Biolohiia tvaryn*, 16(1), 9–20 (in Ukrainian).

Slivinska, L., Maksymovych, I., Tkachenko, H., Andriichuk, A., & Leno, M. (2018). Cardiac enzymes activity and lactate concen- tration in the blood of sport horses at myocardial dystrophy. *Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies*, 20(83), 162–167. doi: 10.15421/nvlvet8331.