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THE STATE OF THE IMMUNE SYSTEM OF HORSES IN CONDITIONS OF STRESS

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The study assessed the impact of adverse conditions of feeding and keeping horses on the state of their non-specific resistance. Morphological indicators of blood (hemoglobin content, number of erythrocytes and leukocytes), as well as indicators of humoral (BASC, LASC) and cellular link of innate immunity (phagocytic activity of leukocytes) were used. During the experiment, the horses had a satisfactory general clinical condition, and the main physiological indicators (body temperature, arterial pulse frequency, number of respiratory movements) were within the age norm. It is important to note that there was no significant difference between these parameters in animals at different time periods, which indicated a stable physiological state of the horses at the beginning and at the end of the experiment.

The results of the study showed that long-term stress can cause changes in the hematological and biochemical parameters of horses. For example, the level of hemoglobin in clinically healthy horses was 136 ± 2.2 g/l, but after exposure to stress factors it decreased to 110 ± 1.8 g/l ($p < 0.001$). At the stage of adaptation, the hemoglobin level increased to 124 ± 2.6 g/l ($p < 0.01$) and almost reached the values of clinically healthy horses (132 ± 3.2 g/l) at rest. The number of erythrocytes in clinically healthy horses was 8.8 ± 0.1 T/l. Under stress, this indicator increased to 9.8 ± 0.2 T/l ($p < 0.01$), but decreased to 9.6 ± 0.2 T/l ($p < 0.05$) at the stage of adaptation and reached the lowest level at rest — 8.6 ± 0.1 T/l. A decrease in the number of leukocytes under the influence of stress has been confirmed by our research. In clinically healthy horses, the number of leukocytes was 6.7 ± 0.3 G/l, while under stress this indicator decreased to 5.3 ± 0.2 g/l ($p < 0.001$). At the stage of adaptation, the number of leukocytes increased to 5.5 ± 0.3 g/l ($p < 0.01$) and was 6.2 ± 0.3 G/l at rest.

Stress also affected the indicators of non-specific resistance. In clinically healthy horses, the level of BASC was $85 \pm 1.8\%$, but under stress this indicator decreased to $70 \pm 2.1\%$ ($p < 0.001$). At the stage of adaptation, BASK increased to $75 \pm 1.1\%$ ($p < 0.01$), and at rest it was $82 \pm 1.7\%$. The level of LASK in clinically healthy horses was $35 \pm 0.2\%$, but under stress this indicator decreased to $28 \pm 0.4\%$ ($p < 0.001$). At the stage of adaptation, LASK increased to $30 \pm 0.2\%$ ($p < 0.001$) and reached $36 \pm 0.5\%$ at rest. The phagocytic activity of leukocytes in clinically healthy horses was $60 \pm 1.5\%$, but under stress this indicator decreased up to $50 \pm 1.1\%$ ($p < 0.001$). At the stage of adaptation, phagocytic activity increased to $55 \pm 0.5\%$ ($p < 0.01$) and was $63 \pm 0.9\%$ ($p < 0.05$) at rest.

Thus, the results of our study confirm that stress negatively affects the hematological and biochemical parameters of horses, as well as their non-specific resistance.

Key words: immune system, lymphocytes, immunoglobulins.



СТАН ІМУННОЇ СИСТЕМИ КОНЕЙ В УМОВАХ СТРЕСУ

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В дослідженні було оцінено вплив несприятливих умов годівлі та утримання коней на стан їх неспецифічної резистентності. Були використані морфологічні показники крові (вміст гемоглобіну, кількість еритроцитів та лейкоцитів), а також показники гуморальної (БАСК, ЛАСК) та клітинної ланки вродженого імунітету (фагоцитарна активність лейкоцитів). Під час експерименту коні мали задовільний загальний клінічний стан, а основні фізіологічні показники (температура тіла, частота артеріального пульсу, кількість дихальних рухів) знаходилися в межах вікової норми. Важливо зазначити, що між цими показниками у тварин в різні періоди часу не було достовірної різниці, що свідчило про стабільний фізіологічний стан коней на початку та в кінці дослідження.

Результати дослідження показали, що тривалий стрес може викликати зміни у гематологічних і біохімічних параметрах коней. Наприклад, рівень гемоглобіну у клінічно здорових коней становив $136 \pm 2,2$ г/л, але після дії стресових факторів він знизився до $110 \pm 1,8$ г/л ($p < 0,001$). На стадії адаптації рівень гемоглобіну підвищився до $124 \pm 2,6$ г/л ($p < 0,01$) і майже досяг показників клінічно здорових коней ($132 \pm 3,2$ г/л) в стані спокою. Кількість еритроцитів у клінічно здорових коней була $8,8 \pm 0,1$ Т/л. Під стресом цей показник зріс до $9,8 \pm 0,2$ Т/л ($p < 0,01$), але знизився до $9,6 \pm 0,2$ Т/л ($p < 0,05$) на стадії адаптації і досяг найнижчого рівня в стані спокою — $8,6 \pm 0,1$ Т/л. Зниження кількості лейкоцитів під впливом стресу підтверджено нашими дослідженнями. У клінічно здорових коней кількість лейкоцитів становила $6,7 \pm 0,3$ Г/л, тоді як під стресом цей показник знизився до $5,3 \pm 0,2$ Г/л ($p < 0,001$). На стадії адаптації кількість лейкоцитів підвищилася до $5,5 \pm 0,3$ Г/л ($p < 0,01$) і становила $6,2 \pm 0,3$ Г/л в стані спокою.

Стрес також впливав на показники неспецифічної резистентності. У клінічно здорових коней рівень БАСК становив $85 \pm 1,8$ %, але під стресом цей показник знизився до $70 \pm 2,1$ % ($p < 0,001$). На стадії адаптації БАСК підвищився до $75 \pm 1,1$ % ($p < 0,01$), а в стані спокою становив $82 \pm 1,7$ %. Рівень ЛАСК у клінічно здорових коней становив $35 \pm 0,2$ %, але під стресом цей показник знизився до $28 \pm 0,4$ % ($p < 0,001$). На стадії адаптації ЛАСК підвищився до $30 \pm 0,2$ % ($p < 0,001$) і досяг $36 \pm 0,5$ % в стані спокою. Фагоцитарна активність лейкоцитів у клінічно здорових коней становила $60 \pm 1,5$ %, але під стресом цей показник знизився до $50 \pm 1,1$ % ($p < 0,001$). На стадії адаптації фагоцитарна активність підвищилася до $55 \pm 0,5$ % ($p < 0,01$) і становила $63 \pm 0,9$ % ($p < 0,05$) в стані спокою.

Таким чином, результати нашого дослідження підтверджують, що стрес негативно впливає на гематологічні та біохімічні параметри коней, а також на їх неспецифічну резистентність.

Ключові слова: імунна система, лімфоцити, імуноглобуліни.



Introduction. In response to the impact of the strongest adverse environmental factors, a special state of adaptation known as stress develops in the animal body, which is a non-specific response of the body to any demand placed on it.

The negative impact of stress affects the whole body and, above all, the immune system. Due to its sensitivity, it can serve as an indicator of stress loads. Stressed animals are more sensitive to infectious agents, inflammatory processes, tumor diseases. Violations of the activity of both the innate and the acquired immune system are manifested in the form of an immunodeficiency state (Bartolomé E., & Cockram M. S., 2016, Asha K, Das B., & Nagar K. K., 2023).

The main stress factors that cause the immunodeficiency state of animals are insufficient or unbalanced nutrition, in particular, a deficiency of protein, vitamins and trace elements in the diet, violation of housing conditions, the effect of toxic substances, climatic and microclimatic factors (DeNotta S., & McFarlane D., 2023) In the process of evolution, animals have developed effective protective mechanisms that neutralize or prevent the penetration of microorganisms into the internal environment of the body. These mechanisms and structural elements of the body form a powerful defense system. The body's immune system provides immunity, which is a way of protection against the effects of various substances and organisms that disrupt the structure and functions of the body. It includes a set of organs and tissues that protect the body from pathogens, which can be of different sizes: from viruses to endoparasites. Being in conditions of constant stress, horses have significant changes in the state of the immune system (Khummuang S. et al., 2020, Miller A. B. et al., 2021).

According to modern concepts, the immune system is divided into two parts - innate (non-specific, hereditary) and adaptive (specific, acquired), which is the result of a long evolutionary development of defense mechanisms, which created an effective multi-level system.

The structures and mechanisms belonging to the factors of innate immunity include physical, chemical and biological barriers that prevent the penetration of pathogens into the body. Physical barriers include the skin and mucous membranes, which provide mechanical protection and removal of pathogens due to the moisture of mucus, tears, urine, and the contraction of the cilia of the ciliated epithelium in the respiratory tract. These protective barriers are significantly affected by various stress factors, such as increased environmental temperature, emotional stress, increased physical activity, transportation, etc. (Staley M. et al., 2018, Alhindy M. K., Borovkov S., & Tymoshenko O., 2024)

Humoral factors of innate immunity are represented by systems of complement, interferon, proteins of the acute phase, as well as lysozyme. The complement system assists phagocytes and antibodies in neutralizing pathogenic microorganisms and is a cascade system of proteolytic enzymes that consists of approximately 25 simple proteins and glycoproteins. These proteins are synthesized mainly in the liver and make up about 5% of the total globulin fraction of blood plasma. Like other components of the immune system, the complement system is activated before it can function effectively against pathogens. It is known that these components have changes under various stress factors, which was noted in the works of many researchers (Stull C. L. et al., 2004, Stefurak I. V., Pasaylyuk M. V., & Stefurak Yu. P., 2015).

One of the important methods of researching the state of non-specific resistance of the body is the determination of the bactericidal activity of blood serum, which means the ability to delay and inhibit the growth of microorganisms. This property is due to the content of lysozyme, complement, properdin, and interferon in blood serum, which reflects the combined effect of humoral protective factors. The bactericidal



activity of blood serum depends on the age of the animals, the season, conditions of feeding and care, stress factors, etc.

The purpose of our work was to investigate the influence of stress factors caused by military actions (emotional stress, violation of feeding and keeping conditions) on the state of non-specific resistance of horses of the Ukrainian riding breed.

Research materials and methods. For research, 9 horses kept in the equestrian sports complex of the State Biotechnological University were selected. 7 heads of male and female horses of the Ukrainian riding breed, 1 head of weight carriers, 1 head of half-breeds were examined. Horses were examined before the start of active hostilities, during their stay on the territory of the equestrian complex, during them and a month after evacuation.

Blood tests were performed at the laboratories of the National Scientific Center "Institute of Experimental and Clinical Veterinary Medicine", Kharkiv.

During the research, the bioethical norms of treatment of animals were observedⁱⁱⁱⁱⁱⁱ.

Blood morphological indicators and hemoglobin content were determined by generally accepted methods. Phagocytosis studies were carried out according to V. S. Gostev, modified by S. I. Plyashchenko (1979).

The obtained digital indicators were processed by mathematical methods. The arithmetic mean (M), statistical error of the arithmetic mean (m) was determined. The probability of the difference between the arithmetic mean of two variational series was determined by the reliability criterion (td) and by Student's tables and the non-parametric Van der Waerden method. The difference between the two values was considered reliable by * - $p \leq 0.05$; ** – $p \leq 0.01$; *** – $p \leq 0.001$.

Research results.

The influence of unfavorable conditions of feeding and keeping horses on the state of non-specific resistance was judged by the morphological indicators of blood (hemoglobin content, number of erythrocytes and leukocytes), indicators of the humoral (BASC, LASC) and cellular link of innate immunity (phagocytic activity of leukocytes, phagocytic index).

During the experiment, the horses had a satisfactory general clinical condition, the main physiological indicators (body temperature, arterial pulse frequency, number of respiratory movements) were within the age norm. Moreover, it should be noted that there was no significant difference between these indicators in animals at different time periods, which indicated the same physiological state of the horses at the beginning of the experiment and at its end. Also important is the lack of difference in physiological parameters in horses at the end of the experiment.

The results of our study showed that long-term stress can cause changes in some hematological and biochemical parameters in horses (Table 1).

Stress hormones such as cortisol and epinephrine can affect the bone marrow by suppressing red blood cell production. This can lead to a decrease in the number of new red blood cells in the blood, which lowers the level of hemoglobin. Thus, the hemoglobin level in clinically healthy horses is 136 ± 2.2 g/l, after exposure to stress factors it decreased to 110 ± 1.8 g/l ($p \leq 0.001$), and in the adaptation stage the

ⁱ General ethical principles of animal experiments (adopted at the First National Congress on Bioethics; Kyiv, 2001)

ⁱⁱ European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986)

ⁱⁱⁱ Law of Ukraine "On the Protection of Animals from Cruelty" (2021 edition)



hemoglobin level increases to $124 \pm 2,6$ g/l ($p \leq 0.01$), and approaches the indicators of clinically healthy horses, being 132 ± 3.2 g/l at rest. Also, stress can cause an oxidative effect that damages the membranes of erythrocytes and leads to their accelerated destruction. This can lower hemoglobin levels because the body does not have time to produce new red blood cells fast enough to compensate for the loss.

Table 1

Indicators of natural resistance of horses (M±m, n=9)

Indicator	Clinically healthy horses	Indicators under stress conditions	The indicator is in the stage of adaptation	Indicators at rest
Hemoglobin, g/l	$136 \pm 2,2$	$110 \pm 1,8^{***}$	$124 \pm 2,6^{**}$	$132 \pm 3,2$
Erythrocytes, T/l	$8,8 \pm 0,1$	$9,8 \pm 0,2^{**}$	$9,6 \pm 0,2^*$	$8,6 \pm 0,1$
Leukocytes, g/l	$6,7 \pm 0,3$	$5,3 \pm 0,2^{***}$	$5,5 \pm 0,3^{**}$	$6,2 \pm 0,3$
BASK, %	$85 \pm 1,8$	$70 \pm 2,1^{***}$	$75 \pm 1,1^{**}$	$82 \pm 1,7$
LASK, %	$35 \pm 0,2$	$28 \pm 0,4^{***}$	$30 \pm 0,2^{***}$	$36 \pm 0,5$
Phagocytic activity of leukocytes, %	$60 \pm 1,5$	$50 \pm 1,1^{***}$	$55 \pm 0,5^{**}$	$63 \pm 0,9^*$

*Note: * - $p \leq 0.05$, ** - $p \leq 0.01$, *** - $p \leq 0.001$ compared to the indicators of the control group.*

The number of erythrocytes in clinically healthy horses is 8.8 ± 0.1 T/l. Under the influence of stress, their number increases to 9.8 ± 0.2 T/l ($p \leq 0.01$), which is a significant change, in the adaptation stage this indicator decreases to 9.6 ± 0.2 T/l ($p \leq 0.05$), and at rest it becomes the smallest - 8.6 ± 0.1 T/l.

The reduction in red blood cell levels due to stress is supported by various studies that indicate that stress causes a decrease in red blood cell production in the bone marrow due to exposure to cortisol and other stress hormones.

The content of leukocytes in clinically healthy horses is 6.7 ± 0.3 g/l. Under the influence of stress, this indicator decreases to 5.3 ± 0.2 g/l ($p \leq 0.001$), and in the adaptation stage the number of leukocytes increases to 5.5 ± 0.3 g/l ($p \leq 0.01$) and in at rest is 6.2 ± 0.3 g/l.

Research shows that stress can cause a decrease in white blood cell levels in horses. Cortisol, one of the main stress hormones, can have an immunosuppressive effect. It can suppress the production of white blood cells in the bone marrow and reduce the activity and life expectancy of white blood cells already present in the blood. Stress can stimulate the release of cytokines, which promote the migration of leukocytes from the bloodstream to sites of possible inflammation or damage. This leads to a decrease in their number in the peripheral blood. Various studies confirm a decrease in the level of leukocytes under the influence of stress.

Indicators of non-specific resistance have also undergone significant changes, so in clinically healthy horses the level of BASK is $85 \pm 1.8\%$. Under the influence of stress, this indicator decreases to $70 \pm 2.1\%$ ($p \leq 0.001$), and in the stage of adaptation, BASK increases to $75 \pm 1.1\%$ ($p \leq 0.01$), while at rest it is $82 \pm 1.7\%$.

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horses, being 132 ± 3.2 g/l at rest. Also, stress can cause an oxidative effect that damages the membranes of erythrocytes and leads to their accelerated destruction. This can lower hemoglobin levels because the body does not have time to produce new red blood cells fast enough to compensate for the loss.

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Indicators of non-specific resistance have also undergone significant changes, so in clinically healthy horses the level of BASK is $85 \pm 1.8\%$. Under the influence of stress, this indicator decreases to $70 \pm 2.1\%$ ($p \leq 0.001$), and in the stage of adaptation, BASK increases to $75 \pm 1.1\%$ ($p \leq 0.01$), while at rest it is $82 \pm 1.7\%$.

Stress hormones such as cortisol and epinephrine can affect the bone marrow by suppressing red blood cell production. This can lead to a decrease in the number of new ones.

In clinically healthy horses, LASK is $35 \pm 0.2\%$. Under the influence of stress, this indicator decreases to $28 \pm 0.4\%$ ($p \leq 0.001$), at the same time in the stage of adaptation LASK increases to $30 \pm 0.2\%$ ($p \leq 0.001$), and in a state of rest it is $36 \pm 0.5\%$. Bactericidal and lysozyme activity of blood serum are important indicators of the state of the immune system, which reflect the body's ability to fight bacterial infections. Under the influence of stress, these indicators can change due to various physiological and biochemical mechanisms.

The phagocytic activity of leukocytes in clinically healthy horses was $60 \pm 1.5\%$. Under stress, this indicator decreases to $50 \pm 1.1\%$ ($p \leq 0.001$), which is a very significant change. In the stage of adaptation, phagocytic activity increases to $55 \pm 0.5\%$ ($p \leq 0.01$), and at rest it is $63 \pm 0.9\%$ ($p \leq 0.05$), which may be a consequence of the fact that stress can affect the endocrine system, which regulates the immune response, including the activation of phagocytes. Changes in the levels of cytokines and other inflammatory mediators can affect the function of phagocytes.

Discussion. During stress reactions, red blood cells play a key role in transporting oxygen between the lungs and other tissues. In this study, the number of erythrocytes in the blood of Ukrainian riding horses was significantly higher during the stress response, and conversely, the hemoglobin level was significantly lower during chronic stress, indicating unformed erythropoiesis in horses. However, it notes that



there is a possibility that a decrease in the volume of plasma in the blood will cause an increase in the number of red blood cells (Horne T. M., 2018).

Changes in feeding and housing conditions, as well as an increase in the temperature of the external environment cause the mobilization and activation of leukocytes, platelets and factors of non-specific resistance. Muscle degradation during stress reactions can activate numerous inflammatory reactions. This stress-induced mechanism involves not only muscle tissue, but also peripheral blood cells, such as leukocytes, which are important components of the immune system (Valle E. et al., 2015). In addition, the bactericidal activity of blood serum is determined by the ability of the serum to destroy bacteria. This indicator depends on the concentration and activity of various antimicrobial proteins and enzymes in the serum, such as complement and antibodies (Stefurak Yu. P., Pasailiuk M. V., & Stefurak I. V. 2014).

Stress can reduce the activity of the complement system, which is an important part of innate immunity. Stress hormones, such as cortisol, can suppress the synthesis of complement components, reducing its bactericidal activity. Also, cortisol and other stress hormones can have an immunosuppressive effect, reducing the overall effectiveness of the immune response, which includes the bactericidal activity of the serum, negatively affecting the functioning of neutrophils and other cells that produce lysozyme, which can also reduce its level in the serum (Wilson J. et al., 2023).

Conclusions. Thus, stress can significantly affect indicators of nonspecific immunity and phagocytic activity of leukocytes in horses through various mechanisms, including hormonal influence and changes in immune regulation.

Further research and understanding of these changes is an important factor for the formation of measures to support the immune system of animals under conditions of stress.

References

- Alhindy, M. K., Borovkov, S., & Tymoshenko, O. (2024). Marker changes in the blood lipidogram in the pathogenesis of some internal diseases of horses. *Ukrainian Journal of Veterinary Sciences*, 15(1), 9–23. <https://doi.org/10.31548/veterinary1.2024.09>
- Asha, K, Das, B., & Nagar, K. K. (2023). An Analysis of Managing Stress Response in Horses to Prevent Laminitis. *Revista Electronica De Veterinaria*, 24(2), 400-408. Retrieved from: <https://www.veterinaria.org/index.php/REDVET/article/view/356>
- Bartolomé, E., & Cockram, M. S. (2016). Potential effects of stress on the performance of sport horses. *Journal of Equine Veterinary Science*, 40, 84–93. <https://doi.org/10.1016/j.jevs.2016.01.016>
- DeNotta, S., & McFarlane, D. (2023). Immunosenescence and inflammaging in the aged horse. *Immunity & ageing : I & A*, 20(1), 2. <https://doi.org/10.1186/s12979-022-00325-5>
- Horne, T. M. (2018). *Impact of stressors on immune system parameters in yearling horses and fermentation characteristics and aerobic stability of inoculated corn silages* (Doctoral dissertation, Kansas State University).
- Khummuang, S., Lee, H. G., Joo, S. S., Park, J. W., Choi, J. Y., Oh, J. H., Kim, K. H., Youn, H. H., Kim, M., & Cho, B. W. (2020). Comparison for immunophysiological responses of Jeju and Thoroughbred horses after exercise. *Asian-Australasian journal of animal sciences*, 33(3), 424–435. <https://doi.org/10.5713/ajas.19.0260>



- Miller, A. B., Harris, P. A., Barker, V. D., & Adams, A. A. (2021). Short-term transport stress and supplementation alter immune function in aged horses. *PloSone*, 16(8), e0254139. <https://doi.org/10.1371/journal.pone.0254139>
- Staley, M., Conners, M. G., Hall, K., & Miller, L. J. (2018). Linking stress and immunity: Immunoglobulin A as a non-invasive physiological biomarker in animal welfare studies. *Hormones and behavior*, 102, 55–68. <https://doi.org/10.1016/j.yhbeh.2018.04.011>
- Stefurak, I. V., Pasaylyuk, M. V., & Stefurak, Yu. P. (2015). Vliyanie paratipicheskikh faktorov na pokazateli nespetsificheskoy rezistentnosti organizma loshadey gutsul'skoy porody. *Nauchno-tekhnicheskii byulleten' Instituta zhivotnovodstva Natsional'noy akademii agrarnykh nauk Ukrainy*, (114), 147–154. (In Russian).
- Stefurak, Yu. P., Pasailiuk, M. V., & Stefurak, I. V. (2014). Pryrodna rezystentnist konei riznykh porid. *Naukovo-tekhnichniy biuleten*, (111), 300–306. (in Ukrainian)
- Stull, C. L., Spier, S. J., Aldridge, B. M., Blanchard, M., & Stott, J. L. (2004). Immunological response to long-term transport stress in mature horses and effects of adaptogenic dietary supplementation as an immunomodulator. *Equine veterinary journal*, 36(7), 583–589. <https://doi.org/10.2746/0425164044864589>
- Valle, E., Zanatta, R., Odetti, P., Traverso, N., Furfaro, A., Bergero, D., Badino, P., Girardi, C., Miniscalco, B., Bergagna, S., Tarantola, M., Intorre, L., & Odore, R. (2015). Effects of competition on acute phase proteins and lymphocyte subpopulations - oxidative stress markers in eventing horses. *Journal of animal physiology and animal nutrition*, 99(5), 856–863. <https://doi.org/10.1111/jpn.12289>
- Wilson, J., De Donato, M., Appelbaum, B., Garcia, C. T., & Peters, S. (2023). Differential Expression of Innate and Adaptive Immune Genes during Acute Physical Exercise in American Quarter Horses. *Animals an open access journal from MDPI*, 13(2), 308. <https://doi.org/10.3390/ani13020308>