Praca oryginalna *Original paper*

Use of magnetic field in equine physiotherapy: a preliminary study

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Received 25.06.2020 *Accepted 17.11.2020*

Jastrzębska E.

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Summary

This study aimed to determine the efficacy of magnetic field therapy in equine rehabilitation and the use of thermography as a diagnostic tool providing visualisation of the healing progress. The material for the study was a 23-year-old Mur-Insulan mare used for many years as a horse for riding lessons. Magnetic field therapy was applied every second day for 60 minutes. During the survey, blood samples were taken three times. Thermograms were taken before and after each magnetic therapy sessions. Magnetic field therapy had no negative effects on the mare's condition, which was supported by haematological blood samples analysis. Thermograms showed increased temperature within the examined front limbs and trunk. During the sessions, the mare was calm and relaxed, which indicates that the application of a magnetic field had a calming and soothing effect on the horse's body. The conclusion was that magnetic field therapy may improve regeneration, provides proper cell nutrition, faster bone symphysis, analgesia and could decrease swelling.

Keywords: horses, physical therapy, thermography

Physiotherapy is currently becoming increasingly popular (15). It starts from natural reserves therapy and it has been used for many years (29). The main concept of physiotherapy is the use of different types of physical energy. This energy stimulates self-defense mechanisms and prevents the development of diseases or can remove the negative effects of various pathological processes (50). Physiotherapy is now recommended to be used along with pharmacotherapy and surgical management (8, 29, 35, 41). Magnetic and electromagnetic fields, which are bioelectric phenomenon, have existed since the beginning of the universe. These natural forces existed long before the appearance of the world of plants and animals and had a huge impact on the basic life functions of all bodies. Both humans and animals are exposed to the external magnetic field and all processes taking place within the tissues are dependent on electromagnetic forces (7, 54). Zoophysiotherapy may improve the quality of life and decrease painful reactions which are observed in pathological states. It can also decrease the time needed for regeneration after surgical procedures or diseases related to contemporary civilization (29, 54, 65). It could be applied in small animal medicine as well as in large animals, especially horses (7, 29, 54).

Thermography is a diagnostic technique which has a wide range of uses in various fields, such as human medicine, veterinary medicine and the energy, military and construction industries (43, 52, 59). This non-invasive technique is based on detecting emitted radiation, which is used to create images. This can be used to determine temperature dispersion within the body (7) and may help determine the efficacy of a physiotherapeutic program.

This study aimed to determine the efficacy of magnetic field therapy in equine rehabilitation and the use of thermography as a diagnostic tool providing a visualisation of the healing progress.

Material and methods

The material for the study was a 23-year-old Mur-Insulan mare. During the study, the mare was kept at the University of Warmia and Mazury in the Olsztyn Equestrian Centre. For many years the mare was used as a pleasure riding horse; however, for a few months she was withdrawn from work due to age. Her calm temperament, patience, no stereotypical behaviour and tolerance for unexpected visual and auditory stimulus made her ideal for the study.

Magnetic field therapy was performed using a pulsatile magnetic field G-pulse 210 μP/300 Emitter in the form of saddle-clothing or limb pads. Therapy was applied every second day for 60 minutes using programs suggested by the producer (frequency 4-25 Hz, induction 2-10 mT). Blood samples were taken during the survey. The first sample was collected before the beginning of the study, the second

sample was collected nine days after the beginning of the study and the third sample was collected after 28 days, at the end of the study. The measured parameters were: total protein level (TP), magnesium (Mg) and calcium (Ca). Blood analysis was performed using an ACCENT- 200 Cormay biochemical analyser. Other parameters were haematological indices, including red blood cells (RBC), white blood cells (WBC), platelets (PLT), haemoglobin level (HGB), haematocrit (HCT) and the analysis was conducted using a haematological analyser ADIVA 2120i Siemens.

The thermal imaging method using a thermal imaging camera FLIR T250 (resolution: 320 × 240, spectral range: 7.5-13 µm and temperature range: from –20°C to +350°C) was used for diagnostic purposes. Each time the mare was examined, two images were taken: before and after the treatment session. Each thermogram was done in three planes: dorsal, right lateral view (body, front limb) and left lateral view (body, front limb). Non-invasive temperature measurements recorded variabilities in heat conduction within the skin. The results were presented as a temperature gradient map. Thermography was used to detect any inflammatory process (which is characterised by increased local temperature) (43, 52).

Results and discussion

The results obtained from blood samples (Tab. 1) were mostly within the reference ranges according to Winnicka (64). Total protein, red blood cells, white blood cells, haemoglobin and haematocrit levels were within normal values, which were similar to reference ranges. Calcium (Ca), magnesium (Mg) and thrombocyte (PLT) parameters were out of the reference ranges, and calcium levels were slightly increased. Magnesium levels were higher during the rehabilitation program, although at the end of the study the magnesium level was quite low, probably due to the low intake with diet. The concentration of platelets in the mare blood test during the study decreased significantly, and the final blood draw was lower than the correct ranges. But if the platelet concentration is compared to other references (whose ranges were between 100-600 thou/µl), the results from the mare used in the study are within the lower limit values.

After analysis of the results obtained from thermography, the superficial body temperature range was established, mainly the front limbs and trunk. The main goal of thermography was to establish the efficacy of magnetic field therapy. Each thermogram has a scale consisting of various colours. White to red colours indicate body surfaces with higher temperature, while yellow to green and blue to violet colours indicate lower temperatures. After each magnetic therapy session, the temperature of the examined body surfaces was elevated (Fig. 1-3), which is associated with increased blood flow in a specific area. This leads to the conclusion that magnetic field therapy may improve regeneration, provides proper cell nutrition, faster bone symphysis, analgesia and may decrease swelling.

Haematological and biochemical parameters are useful tools for animal clinics. The results of biochemical indices of mare blood are within the reference values given by different authors (64). Total protein, red blood cells, white blood cells, haemoglobin and haematocrit levels were within normal values, which were similar to reference results in other studies (24, 39, 56). The results of haematological parameters of mare blood were different from those obtained by Lacerda et al. (25), Berlin and Aroch (5), Fonteque et al. (17), Mikniene et al. (34). Some authors (49) observed that older horses (> 8 years) had higher leukocyte values than younger horses. However, Snow et al. (51) reported no effect of age on the haematological parameters of thoroughbreds, while Veiga et al. (61), Howard et al. (20), Ribeiro et al. (46), Diaz et al. (13), working with different breeds, observed a greater influence attributable to age in the haematological values of young horses. The differences in haematological values among breeds are reported in literature, emphasizing erythrocyte value differences between thoroughbreds and cold-bloods (37). Studies with Andalusian horses, an ancestor of the Brazilian Criollo horse, show higher haematological values than the Criollo horse (38), suggesting that the adaptation process generated physiological changes (25). In the literature, however, the work did not indicate differences in the values of haematological parameters between the horse races (17).

Recently, the number of magnetic products manufactured and promoted for use in animals has increased several-fold. However, the biological cellular or subcellular effects are complex and still under debate (8, 12, 22, 23, 53, 63). The effects of magnets on various parameters have been investigated on humans (11, 14), rats (21, 36), mice (66) and rabbits (18) with few equine studies (22, 53, 60). The reported effects of static magnets on blood flow and pain are conflicting (10, 14, 21, 22, 33, 40, 42, 53), partly

Tab. 1. Haematological results

Parameter	Unit	I blood collection	II blood collection	III blood collection	Average	Reference range by Winnicka (64)
Total protein	g/l	67.3	66.9	66.8	67.00	60.0-78.0
Calcium	mmol/l	3.20	3.29	3.13	3.21	2.25-3.12
Magnesium	mmol/l	0.53	0.54	0.62	0.56	0.70-1.15
Red blood cells	mln/µl	8.83	8.13	8.59	8.52	5.50-10.0
Leucocytes	thou/µl	7.37	8.13	8.02	7.84	5.50-12.0
Platelets	thou/µl	195 000	181 000	136 000	170 600	150 0000-400 000
Haemoglobin	g/dl	13.9	12.9	13.7	13.5	8.00-18.00
Haematocrit	%	42.90	39.10	40.40	40.80	24.00-52.00

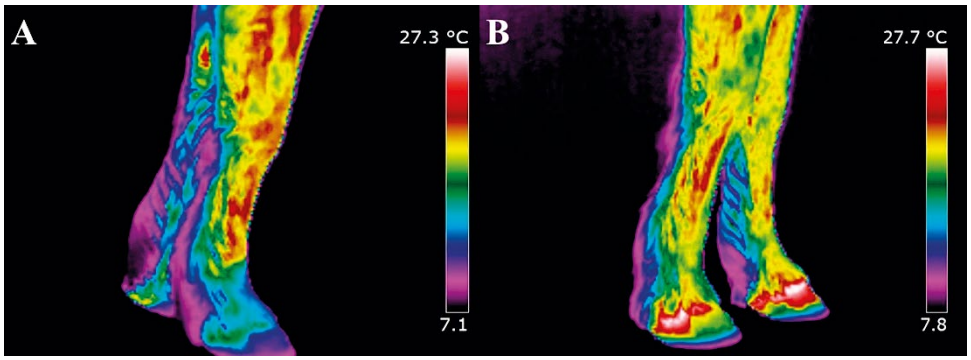

Fig. 1. Lateral view of the front limbs before (A) and after (B) magnetic field therapy

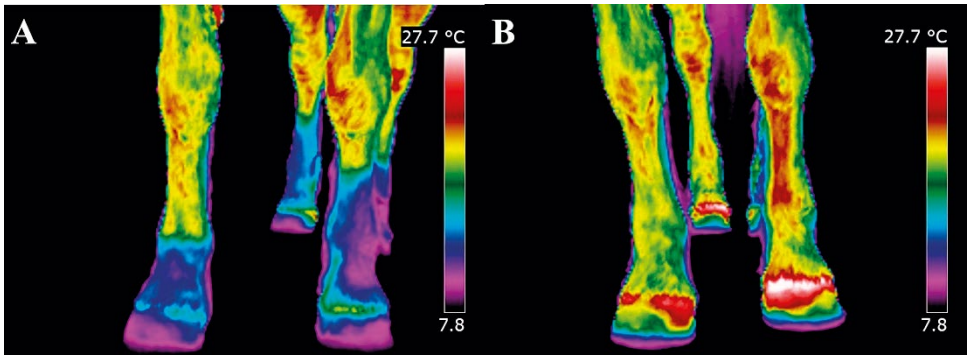

Fig. 2. Dorsal view of the front limbs before (A) and after (B) magnetic field therapy

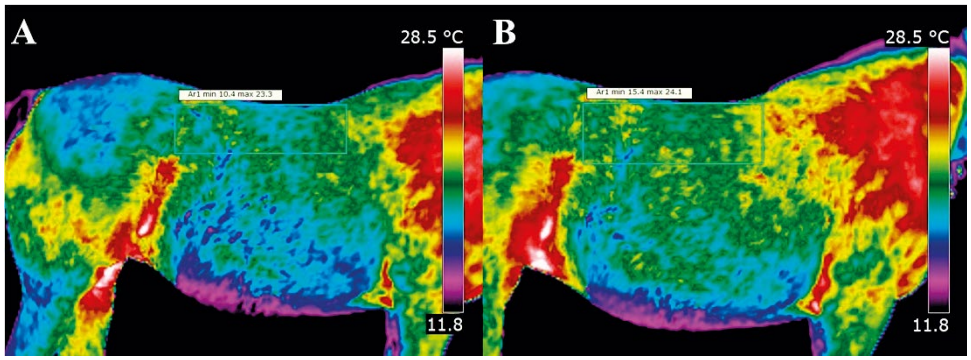

Fig. 3. Lateral view of the body before (A) and after (B) magnetic field therapy

due to difficulties in assessing the treatment outcome. Ramey (44) provided a thorough review of all aspects of physiological and clinical effects of static and pulsed electromagnetic field therapies. First mentioned in horses by Flynn (16), electromagnetic field therapy was introduced by Auer et al. (1), who described the general background and possible applications of these therapies in equine bone healing. Static or pulsating magnetic fields have been used in the prevention of disease or in the treatment of muscle soreness, delayed wound healing and pain (15). According to Kobluk et al. (22), Sieron et al. (50), Bromiley (7), Stopyra et al. (54), Marczak (29), Cane et al. (9) magnetic field therapy could improve regeneration, provides proper cell nutrition, faster bone symphysis, analgesia and could decrease swelling.

In the current study, the effects of relaxation and calming by a magnetic field were observed. However, Edner et al. (15) observed that horses treated with magnetic field therapy and a control group covered by a placebo blanket were found to have no significant differences in behavioural traits between treatment groups; only a time-related effect was seen, indicating that both blankets affected the horses in a similar way, making them slightly more relaxed. This observation could also be an effect of time. The use of two different protocols to assess behaviour somewhat reduced the risk of a false negative result (30). A possible calming effect of magnets can be assessed by use of ethograms, which register differences in behavioural traits (30, 45).

Thermography is a non-invasive diagnostic method, which could support physiotherapy through the control of the effectiveness of specific rehabilitation programs. To show the positive effects of magnetic field therapy on the animal's health, studies should be performed on a larger group of animals of different age and different condition. Thermography allows exploring the surface temperature of the tissue, indicating the effects of increased blood flow due to the applied magnetic field therapy (28, 57, 58). Skin temperature is often used as an indirect measure of changes in superficial blood flow, since the metabolic rate in healthy skin is rather constant. An increase in blood flow is therefore accompanied by an increase in temperature (3, 28). The increased skin temperature during treatment with either blanket is mainly explained by the insulating effect of the blanket (19). A similar result was obtained by Turner et al. (59) who found no difference in the temperature increase, as measured by thermography, after a 24 h application of a wrap containing a biomagnet compared with a placebo wrap.

In studies of different authors using various methods of testing tissue temperature: the photoplethysmographic (PPG) technique monitors blood flow-related parameters from muscles by the use of a light-emitting diode (LED) and a photodetector placed on the skin (48, 67). In the authors' own research, thermography showed a temperature rise in superficial tissues after the application of magnetic fields emanating from the applicator. The results of previous studies on the effect of static magnets on blood flow in humans and

laboratory animals are inconsistent, some reporting decreases (21, 31) while others describe increases (6, 7, 18, 19, 22, 44) or no effect (2, 4, 15, 26, 32, 47, 53). In these studies, skin blood flow was investigated with various methods. Only one study reported on the effect on muscle blood flow (66).

Different results regarding tissue temperature are due to several factors, for example, the use of anaesthesia, the state of the animal tissue and the time of temperature measurement (58). However, the observed slight increase in temperature would not cause increased muscle relaxation (27). In contrast, other interventions aiming at reducing muscle tension, have resulted in significant differences in mechanical nociceptive threshold values (55, 62).

In conclusion, pulsating magnetic field therapy did not negatively affect the results of haematological and biochemical parameters of mare blood. The animal was calm and relaxed during therapy. Thermographic images taken just after magnetic field therapy showed an increase in the surface temperature of the front of the legs and the horse's back. Since the results of the magnetic field quoted by various authors are inconclusive, further studies are needed on a larger group of horses. The aim of future studies will be to investigate the possible clinical effects of static magnets on blood, skin temperature and behaviour parameters.

References

1. *Auer J., Burch G., Hall P.*: Review of pulsing electromagnetic field therapy and its possible application to horses. Equine Vet. J. 1983, 5, 354-360.
2. *Barker A., Cain M.*: The claimed vasodilatory effect of a commercial permanent magnet foil; results of a double-blind trial. Clin. Phys. Physiol. Meas. 1985, 6, 261-263.
3. *Barnes R.*: Thermography of the human body. Science 1963, 140, 870-877.
4. *Bellossi A., Nicol L., Dazord L.*: No Effect of a Low-Frequency Pulsed Magnetic Field on the Brain Blood Flow Among Mice. Panminerva Med. 1993, 35, 57-59.
5. *Berlin D., Aroch I.*: Concentrations of ionized and total magnesium and calcium in healthy horses: effects of age, pregnancy, lactation, pH and sample type. Vet. J. 2009, 181, 305-311.
6. *Bowman K., Purohit R., Ganjam V., Pechman R., Vaughan J.*: Thermographic evaluation in corticosteroid efficacy in amphotericin b-induced arthritis in ponies. Am. J. Vet. Res. 1983, 44, 51-56.
7. *Bromiley M.*: Equine injury therapy and rehabilitation. Blackwell Publ., Oxford 2008.
8. *Buchner H., Schildboeck U.*: Physiotherapy applied to the horse: a review. Equine Vet. J. 2006, 38, 574-580.
9. *Canè V., Botti P., Farneti D., Soana S.*: Electromagnetic stimulation of bone repair: A histomorphometric study. J. Orthop. Res. 1991, 9, 908-917.
10. *Cepeda M., Carr D., Sarquis T., Miranda N., Garcia R., Zarate C.*: Static magnetic therapy does not decrease pain or opioid requirements: a randomized double-blind trial. Anaesth. Analg. 2007, 104, 290-294.
11. *Colbert A., Wahbeh H., Harling N., Connelly E., Schiffke H., Forsten C., Gregory W., Markov M., Souder J., Elmer P., King V.*: Static magnetic field therapy: a critical review of treatment parameters. Evid. Based Complement. Alternat. Med. 2009, 6, 133-139.
12. *Collier M., Loree R., Antosiewicz P.*: Radioisotope uptake in normal equine bone under the influence of a pulsed electromagnetic field. Mod. Vet. Pract. 1985, 66, 971-974.
13. *Diaz G., Gavidia C., Li E., Tio G.*: Hematologic values, bilirubin and enzyme activities in serum of peruvian paso horses from Lurin valley. Rev. Investig. Vet. Peru 2011, 22, 213-222.
14. *Eccles N.*: A critical review of randomized controlled trials of static magnets for pain relief. J. Altern. Complement. Med. 2005, 11, 495-509.
15. *Edner L., Lindberg H., Broström A., Bergh A.*: Does a magnetic blanket induce changes in muscular blood flow, skin temperature and muscular tension in horses? Equine Vet. J. 2015, 47, 302-307.
16. *Flynn D.*: Enhancement of osteogenesis by electrostimulation – non-invasive technique. Proc. Am. Ass. Equine Practors. 1981, 27, 91-113.
17. *Fonteque J., Ceccatto M., Bagio R., Schade J., Saito M., Martins V., Fonteque G., Martins E., Ramos A., Albuquerque M., Costa D.*: Hematological profile, total plasma protein and fibrinogen concentrations of clinically healthy adult Campeiro horses. Ciência Rural, Santa Maria, Online 2009.
18. *Gmitrov J., Ohkubo C., Okano H.*: Effect of a 0.25 T static magnetic field on microcirculation in rabbits. Bioelectromag. 2002, 23, 224-229.
19. *Havenith G.*: Heat balance when wearing protective clothing. Ann. Occup. Hyg. 1999, 43, 289-296.
20. *Howard D., Fernandes W., Souza A., Leal M., Mirandola R., Benesi F.*: Total protein, albumin and globulin of healthy developing Brazilian Sport Horse (Brasileiro de Hipismo) fillies. Ars Vet. 2008, 24, 77-82.
21. *Ichioka S., Minegishi M., Iwasaka M., Shibata M., Nakatsuka T., Harii K., Kamiya A., Ueno S.*: High-intensity static magnetic fields modulate skin microcirculation and temperature in vivo. Bioelectromag. 2000, 21, 183-188.
22. *Kobluk C., Johnston G., Lauper L.*: A scintigraphic investigation of magnetic field therapy on the equine third metacarpus. Vet. Comp. Orthop. Traumatol. 1994, 7, 9-13.
23. *Kold S., Hickman J., Melsen F.*: Preliminary study of quantitative aspects and the effect of pulsed electromagnetic field treatment on the incorporation of equine cancellous bone grafts. Equine Vet. J. 1987, 19, 120-124.
24. *Krumrych W.*: Laboratory blood indicators – reference values and interpretation. [in Polish] PIWET, Pulawy 2003.
25. *Lacerda L., Campos R., Sperb M., Soares E., Barbosa P., Godinho E., Ferreira R., Santos V., González F.*: Hematologic And Biochemical Parameters In Three High Performance Horse Breeds From Southern Brazil. Arch. Vet. Sci. 2006, 11, 40-44.
26. *Leaper D.*: Do Magnetic Fields Influence Soft Tissue Wound Healing? Equine Vet. J. 1985, 17, 178-180.
27. *Lehmann J.*: Therapeutic Heat and Cold, 4th edn., Williams & Wilkins, Baltimore, Maryland 1990, p. 725.
28. *Love T.*: Thermography as an indicator of blood perfusion. Ann. N. Y. Acad. Sci. 1980, 335, 429-437.
29. *Marczak R.*: Magnetotherapy of dogs and cats. [in Polish] Vet. Per. 2014, 1, 52-56.
30. *Martin P., Bateson P.*: Measuring Behaviour: An Introductory Guide 3rd edn. University Press, Cambridge 2007.
31. *Mayrovitz H., Groseclose E.*: Effects of a static magnetic field of either polarity on skin microcirculation. Microvasc. Res. 2005, 69, 24-27.
32. *Mayrovitz H., Groseclose E., Markov M., Pilla A.*: Effects of permanent magnets on resting skin blood perfusion in healthy persons assessed by laser Doppler flowmetry and imaging. Bioelectromag. 2001, 22, 494-502.
33. *McKay J., Prato F., Thomas A.*: A literature review: the effects of magnetic field exposure on blood flow and blood vessels in the microvasculature. Bioelectromag. 2007, 28, 81-98.
34. *Mikniene Z., Maslauskas K., Kerzienė S., Kučinskienė J., Kučinskas A.*: The effect of age and gender on blood haematological and serum biochemical parameters in žemaitukai horses. Vet. Ir Zoot. 2014, 65, 37-43.
35. *Millis D., Levine D., Taylor R.*: Canine Rehabilitation & Physical Therapy. W.B. Saunders, St Louis 2004.
36. *Morris C., Skalak T.*: Acute exposure to a moderate strength static magnetic field reduces edema formation in rats. Am. J. Physiol. Heart Circ. Physiol. 2008, 294, 50-57.
37. *Morris D.*: Doenças do sistema hemolinfático. [in:] Reed S. M., Bayly W. M.: Medicina Interna Eqüina. Rio de Janeiro, Guanabara Koogan 2000, 481-518.
38. *Muñoz A., Castejón F., Rubio M., Vivo R., Agüera E., Escribano B., Santisteban R.*: How erythrocyte and plasma lactate concentrations are related in Andalusian horses during an exercise test and recuperation. J. Equine Sci. 1996, 7, 35-42.
39. *Neuberg K., Geringer de Oedenberg H.*: The impact of training on selected haematological parameters in horses. [in Polish] Acta Sci. Pol., Zoot. 2007, 6, 59-68.
40. *Ohkubo C., Xu S.*: Acute effects of static magnetic fields on cutaneous microcirculation in rabbits. In Vivo 1997, 11, 221-225.
41. *Pasek J., Misiak A., Mucha R., Pasek T., Sieron A.*: New possibilities in physiotherapy – Magnetolaserotherapy. [in Polish] Fizjoterapia Pol. 2008, 1, 1-10.
42. *Pittler M., Brown E., Ernst E.*: Static magnets for reducing pain: systematic review and meta-analysis of randomized trials. Can. Med. Ass. J. 2007, 177, 736-742.
43. *Purohit R., Mccoy M.*: Thermography in the diagnosis of inflammatory processes in the horse. Am. J. Vet. Res. 1980, 41, 1167-1174.

44. *Ramey D.*: Magnetic and electromagnetic therapy in horses. Comp. Cont. Educ. Pract. Vet. 1999, 21, 553-560.
45. *Ransom J., Cade B.*: Quantifying Equid Behavior – A Research Ethogram for Free-Roaming Feral Horses. U.S. Department of the Interior, Reston, Virginia 2009, p. 1-23.
46. *Ribeiro C., Fagliari J., Galera P., Oliveira A.*: Hematological profile of healthy Pantaneiro horses. Arq. Bras. Med. Vet. Zoot. 2008, 60, 492-495.
47. *Rindler N., Biermann N., Westermann S., Buchner H.*: The effect of pulsed electromagnetic field therapy on surface temperature of horses' backs. Wiener Tierärztliche Monatsschrift 2014, 101, 137-141.
48. *Sandberg M., Zhang Q., Styf J., Gerdle B., Lindberg L.*: Non-invasive monitoring of muscle blood perfusion by photopletysmography: evaluation of a new application. Acta Physiol. Scand. 2005, 183, 335-343.
49. *Schalm O.*: Equine Hematology: Part 2 Thrombocytes and leukocytes. Equine Pract. 1979, 1, 24-35.
50. *Sieron A., Mucha R., Pasek J.*: Magnetotherapy. [in Polish] Reh. w Prakt. 2006, 3, 31-32.
51. *Snow D., Ricketts S., Mason D.*: Haematological response to racing and training exercise in thoroughbred horses, with particular reference to the leucocyte response. Equine Vet. J. 1983, 15, 149-154.
52. *Soroko M., Henklewski R., Filipowski H., Jodkowska E.*: The effectiveness of thermographic analysis in equine orthopedics. J. Equine Vet. Sci. 2013, 33, 760-762.
53. *Steyn P., Ramey D., Kirschvink J., Uhrig J.*: Effect of a static magnetic field on blood flow to the metacarpus in horses. J. Am. Vet. Med. Ass. 2000, 217, 874-877.
54. *Stopyra A., Peczynski Z., Radwinska J.*: Dynamic cell stimulation by a pulsed magnetic field and physical performance of endurance horses. [in Polish] Wet. Prakt. 2011, 9, 76-80.
55. *Sullivan K., Hill A., Haussler K.*: The effects of chiropractic, massage and phenylbutazon on spinal mechanical nociceptive thresholds in horses without clinical signs. Equine Vet. J. 2008, 40, 14-20.
56. *Szarska E.*: The use of blood diagnostic tests to assess the health and advancement of the training of performance horses. [in Polish] Rozprawy Naukowe i Monografie, Publ. SGGW, Warszawa 2003.
57. *Tunley B., Henson F.*: Reliability and repeatability of thermographic examination and the normal thermographic image of the thoracolumbar region in the horse. Equine Vet. J. 2004, 36, 306-312.
58. *Turner T.*: Diagnostic thermography. Vet. Clin. North Am.: Equine Pract. 2001, 17, 95-113.
59. *Turner T.*: Thermography as an aid to the clinical lameness evaluation. Vet. Clin. N. Am. Equine Pract. 1991, 7, 311-338.
60. *Turner T., Wolfsdorf K., Jourdenais J.*: Effects of heat, cold, biomagnets and ultrasound on skin circulation in the horse. Proc. Am. Ass. Equine Practors. 1991, 37, 249-257.
61. *Veiga A., Lopes S., Franciscato C., Oliveira L., Merini L.*: Hematological values, plasma protein and fibrinogen of criollo horse – their variation with sex, age and management. Acta Sci.Vet. 2006, 34, 275-279.
62. *Wakeling J., Barnett K., Price S., Nankervis K.*: Effects of manipulative therapy on the longissimus dorsi in the equine back. Equine Comp. Exerc. Physiol. 2006, 3, 153-160.
63. *Watkins J., Auer J., Morgan S.*: Healing of surgically-created defects on the equine superficial digital flexor tendon: Effects of pulsing electromagnetic field therapy on collagen-type transformation and tissue morphologic reorganization. Am. J. Vet. Res. 46, 1985, 2097-2103.
64. *Winnicka A.*: Reference value of basic laboratory indicators in veterinary medicine. [in Polish] Publ. SGGW, Warszawa 2008.
65. *Wojciechowski R., Sterna J., Lechowski R.*: Application of physical therapy in the treatment of orthopedic diseases in dogs. [in Polish] Życie Wet. 2004, 79, 216-220.
66. *Xu S., Okano H., Ohkubo C.*: Acute effects of whole-body exposure to static magnetic fields and 50-Hz electromagnetic fields on muscle microcirculation in anesthetized mice. Bioelectrochem. 2001, 53, 127-135.
67. *Zhang Q., Lindbergm L., Kadefors R., Styf J.*: A non-invasive measure of changes in blood flow in the human anterior tibial muscle. Eur. J. Appl. Physiol. 2001, 84, 448-452.

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