DOI: 10.1515/fv-2017-0033

FOLIA VETERINARIA, 61, 4: 17—21, 2017

CHANGES IN TEMPERATURE OF THE EQUINE SKIN SURFACE UNDER BOOTS AFTER EXERCISE

Solheim, T. N., Tarabová, L., Faixová, Z.

Institute of pathological physiology, University of Veterinary Medicine and Pharmacy
Komenského 73, 041 81 Košice
Slovakia

lucia.tarabova@uvlf.sk

ABSTRACT

Equine distal limbs have evolved to have long tendons coupled with strong, tendinous muscles positioned proximally on the leg, thus enabling the horse to achieve highly efficient locomotion. The tradeoff is, that the tendons are left unprotected and prone to injuries, therefore they are often protected by various boots and bandages, which may insulate the limbs and cause hyperthermia in the underlying tendons. The actual mechanism for the degeneration of tendons is currently unknown, but damaging temperature increases due to hysteresis in hard-working horses has been suggested as a possible cause. This study compared the skin temperature of the palmar/plantar metacarpal/metatarsal regions of the limbs after exercise with various types of boots and bandages — primarily tendon boots, leather boots and fleece bandages.

Several horses were measured before and after the completion of a standard exercise test. The boots or bandages were removed immediately after the exercise and the temperature was measured at 3 separate places with A Testo 850i infrared thermometer. The differences in temperature increases between the various kinds of boots were compared. The results showed a significantly higher average temperature increase in horses wearing boots or bandages compared to the bare limb. The fleece bandages seemed to accumulate the highest amount of heat, followed by the tendon boots.

Key words: boot; equine limb; temperature; tendon

INTRODUCTION

The horse has become one of the most successful animal athletes and is used at both the amateur and professional levels in numerous types of sporting events. Its athletic capabilities have developed through evolution, from the modern horse´s ancestor; the small Eohippus. Since the first appearance of these animals some 50 million years ago, the horse has evolved into the high-speed, long-legged creatures of modern times [1].

Some of the morphological developments that have imparted advantages for high-speed locomotion include the utilization of the collagenous components of the muscles to reduce energy requirements in posture and locomotion [1]. The proximally positioned muscles are coupled to the long, slender tendons to minimize the weight of the distal limb, thus contributing in enabling the horse to achieve efficient high-speed locomotion [13].

This evolutionary, comparative lack of muscles below the carpus is not entirely without risk. The tradeoff is that the tendons are left unprotected and prone to injuries. A study showed that of all limb injuries (82 % of all incidents) at UK racetracks between the years 1996 and 1998, 46 % were due to flexor tendon and/or suspensory ligament injuries, with a more recent study showing the superficial digital flexor tendon in the forelimb being the most prone to injury [7, 15]. Severe tendon injuries can end the career of a racehorse and even if they do return to racing, their performance may be affected [6, 12]. Seventy per cent of racehorses in Japan with tendon injuries failed to return to their previous level of performance in a single race [12].

Many horse owners choose to try to protect the tendons from injury by applying various kinds of boots and bandages to the limbs during exercise and competitions. These boots and bandages may insulate the limb, thus preventing effective heat loss during exercise, leading to elevated temperatures in the tendons [2, 8]. This elevated temperature might reach damaging levels in the centre of the flexor tendons in horses exercising at maximal effort. Repeated hyperthermic insults may decrease tendon cell viability or alter the tendon cell metabolism and communication – thus affecting the tendon extracellular matrix [3, 4, 9].

The mechanisms of tendon degeneration are generally poorly understood, but it has been hypothesized that the energy increase due to hysteresis may provide one mechanism, predisposing it to subsequent mechanical failure [16].

The aim of this study was to investigate the effect of different types of bandages and boots on the skin temperature of the palmar/plantar aspect of the metacarpus, as measured with an infrared thermometer, on the bare limb before exercise and the booted or bandaged limb after completion of a standard exercise test.

MATERIALS AND METHODS

Animals

Sixteen horses of varying age, sex, and breed were used in this study. All horses were free of lameness and showed no signs of illness or injury, except for horse number 4, which was wearing air boots. We were informed that this horse had an allergic reaction on the left forelimb at the level of the pastern, but showed no signs of pain or lameness before, during or after the standard exercise test.

Instrumentation

A Testo 805i smart probe infrared thermometer with a wireless probe and smartphone operation was used to measure the skin temperature. The thermometer had a measuring range of −30 °C to +250 °C and an accuracy of ±1.5 °C in the range of 0 to +250 °C. The resolution was 0.1 °C and the operating temperature −10 °C to +50 °C. The temperature was measured as close to the leg as possible, due to recommendations of the retailer.

Procedure

The skin temperature of each limb was measured at 3 different places: at the palmar/plantar aspect of the metacarpus/metatarsus — proximally, distally, and in the middle region. The temperature was measured before exercise and directly after completion of the standard exercise test. The boots/bandages on the other limbs were kept on while measurement of the first leg was completed. When the boots were removed, one by one, the temperature was immediately recorded.

Both hind limbs and forelimbs were used in this study. Some horses wore the same type of boots/bandages on both hind limbs and forelimbs, some were fitted with different types on each leg (with one leg bare), and some with boots only on forelimbs or hind limbs. The boots and bandages used in this study were supplied by the horse owners themselves, and might have varied slightly in composition and material. The results for the different boots were pooled into groups according to style and material: traditional tendon boots, fleece bandages, leather tendon boots, traditional boots made from sympatex, traditional boots made of neoprene and tendon "air boots".

The standard exercise test consisted of:

10 minutes of walk,

5 minutes of trot,

2.5 minutes of canter,

5 minutes of walk.

The standard exercise test was conducted both outside and inside in a riding arena, with varying exercise surfaces.

The ambient temperatures varied from −6 °C to 5 °C. The wind speed and humidity were not recorded. Slippery weather conditions (such as snow and ice) made it difficult for some horses exercising outdoors to complete the canter phase of the standard exercise test, and it were partly performed in the trot at a good pace.

Data processing

The average increase in temperature for the different types of boots where calculated and presented in a table with the use of Microsoft Excel.

RESULTS

The results of temperature measurements during the study are presented in Table 1.

Table 1. average temperature increase for the different boots and bandages worn by the horses

Type of boots	Average temperature increase [°C]
Fleece bandages	16.5
Tendon boots	14.3
Leather tendon boots	14.3
Air tendon boots	13.0
Sympatex traditional boots	12.3
Neoprene traditional boots	11.9
Nothing	3.0

These results indicated that the fleece bandages accumulated the most amount of heat during an exercise, followed by the tendon boots and leather tendon boots showing the same average temperature increase. The neoprene traditional boots show the lowest average increase in temperature, followed by the sympatex traditional boots and air tendon boots.

All the boots show a significantly higher average increase in temperature compared with the bare limb after exercise.

The highest measurement observed in this study occurred with the tendon boot, and were observed to be 33.8 °C.

The highest heat measurements were seen at the proximal and distal regions of the limb in fleece bandages, tendon boots and the traditional neoprene boots. The leather tendon boots and the traditional sympatex boots showed a tendency of accumlating the highest amount of heat in the proximal and middle regions.

DISCUSSION

Clothing, or in this case, boots and bandages, acts as a barrier to evaporative and convective cooling. The boots and bandages created a microenvironment between the skin and fabrics, which was generally hotter and more humid than the ambient environment. The temperature and humidity depends on several factors, including the condition of the macroenvironment, movement, permeability of the fabric, encapsulation, and the metabolic heat produced during exercise [5].

The fleece bandages showed the highest average increase in temperature. This correlated well with the results of the thermographic investigation in the study of Westerman et al. [14], where the limbs associated with a fleece bandage were significantly more proximal than that covered with a tendon boot.

The high temperature increase might be due to the insulating properties of the microfleece, causing heat to accumulate under the bandage, or to the fact that it is highly encapsulating compared to the open-fronted boots, covering the entire metacarpal/metatarsal regions of the limbs.

The traditional tendon boots are open-fronted, which possibly could facilitate some air circulation to occur under the tendon boots or allow for some evaporative and convective cooling to occur in the uncovered portions of the equine limb. If this was the case, the temperatures were expected to be lower for these kinds of boots compared to those covering the entire metacarpal or metatarsal regions. In our study, the average temperature increase was lower for the open-fronted tendon boots compared to the fleece bandages, but the traditional neoprene and sympatex boots encapsulating the entire metacarpal/metatarsal regions of the leg showed an even lower average temperature increase. The fact that 3 out of 4 horses wearing traditional neoprene boots did not complete the gallop phase of the standard exercise test, due to slippery exercise conditions, must be taken into consideration as this might have led to lower temperature recordings than may have been seen otherwise if the gallop phase were completed. In comparison, another study found that the open-fronted tendon boots did not result in a relevant reduction in temperature compared to the traditionally fully enclosed boots, which might imply that the thermal properties of the materials used in these boots played just as important a role as the fact that some are open-fronted [8].

The traditional neoprene boots consist of a single layer of neoprene fabric, whilst the tendon boots used consist of either leather, leather with neoprene or a thermoplastic elastomer combined with neoprene. For heat dissipation to occur at the surface of the limb, conduction of heat through both materials for the tendon boots (or a thicker layer in the case of tendon boots consisting only of leather), but only a single layer for the traditional neoprene boots, needs to occur. The thermal conductivity for neoprene is much lower (0.054 W.m.K^{-1}) than that of the thermoplastic elastomers (for example PVC with a thermal conductivity of 0.14—0.17 W.m.K^{-1}), and might be responsible for much of the heat retention in both the traditional neoprene boot and tendon boot, but the added thickness of the thermoplastic elastomer might cause the dissipation of heat to occur at a slower rate, and have significant effects on the accumulation of heat during exercise [17].

In comparing the two tendon boots of similar design apart from their differing material (leather and thermoplastic elastomers/neoprene), no significant difference in average increase of temperature were seen. But, in comparing the tendon boots perforated to allow heat dissipation to tendon boots without perforation, a lower average increase in temperature were observed for the perforated tendon boots. This also correlated well with the results in the study of Hopegood et al. [8] which also indicated that greater heat emissions, and thus heat dissipation, took place in these perforated boots compared to the traditional tendon boots.

Hopegood et al. [8] also found that there were significantly lower heat emissions from the middle of the boot compared to the top and bottom in perforated and traditional tendon boots. This was also true for the fleece bandages, tendon boots and the traditional neoprene boots. The leather tendon boots and the traditional sympatex boots showed a tendency of accumlating the highest amount of heat in the proximal and middle regions. It is unclear whether this was due to a greater insulating effect of the boots in this regions or due to a higher heat production underneath those areas relative to the middle region of the metacarpus/metatarsus.

All horses used in this study were of a sufficient fitness level to cope with the intensity of the standard exercise test, but it was not possible to determine and control the speed of the different horses exercising in this study. The workload is the main determinant of the rate of heat production, and might have varied slightly for each horse. Three of the horses wearing the traditional neoprene boots did not complete the gallop phase of the standard exercise test, and this might have had an impact of the results. In addition, it is not possible to control the natural day-to-day variabilites in the body temperature of the horses.

The temperature was measured with an infrared thermometer, which has been shown to produce accurate measures of skin temperautes [10]. However, the temperature was measured as quickly as possible after the removal of the boots and bandages, some heat might have been allowed to escape before the measurements were completed.

The horses were exercised in different weather conditions and with ambient temperatures ranging from -6 to 5 °C. The skin surface temperature varied in correlation with the ambient temperature, and it might therefore have had an impact on the results in this study [11]. Lastly, the boots and bandages were supplied by the owners of the horses, and might have varied slightly in material and design, which might have affected the results of the present study.These results need to be researched further in larger studies, and the effect of boot materials and design on heat insulation needs to be investigated further.

Westermann et al. [14] suggested that although skin surface temperature in the study paralleled that of deeper tissues, it may not be accuratly indicating the temperature of the underlying tissues and structures. In this study, it was not possible to measure the temperature of the underlaying tendons during or after the exercise with a booted or bandaged limb. Further research could focus on measuring these temperatures during or after exercise with different commercial available boots and bandages.

Furthermore, future research could focus on measuring temperatures during the actual exercise, by use of thermal probes with time-lapse recording equipment or motion thermal imaging camera. It could also be of interest to measure the heart-rate and speed of the horses at the same time. This would allow for the evaluation of temperature development throughout the entire exercise.

CONCLUSIONS

It is clear from the resulting average increase in temperatures that both boots and bandages insulate the limbs during exercise, and could possibly result in detrimental effects on the tendon during high intensity exercise.

The fleece bandages showed the highest average increase, followed by the tendon boots. The perforated tendon boots seem to show a lower increase in temperature compared to the traditional tendon boots. The traditional neoprene boots show the lowest temperature increase, followed by the sympatex traditional boots.

In addition to this, it was found that most of the boots and bandages showed a higher increase in the temperature of the underlying skin in the proximal and distal regions, except for leather tendon boots and sympatex boots, whilst the latter is highly likely due to the low amount of data. These findings point at the importance of the designing of boots and bandages to minimise tendon exposure to high temperatures, but warrants further investigation.

REFERENCES

1. **Back, W., Clayton, H. M., 2001:** *Equine Locomotion*. Harcourt Publishers Ltd., London, 384 pp.
2. **Baxter, K., 2013:** The effect of equine exercise bandages on distal forelimb temperatures during exercise. *South Downs Vet. Phys.*, 1—123.
3. **Birch, H. L., Wilson, A. M., Goodship, A. E., 1997:** The effect of exercise-induced localised hyperthermia on tendon cell survival. *J. Exp. Biol.*, 200, 1703—1708.
4. **Burrows, S., Patterson-Kane, J., Fleck, R., Becker, D., 2009:** Alterations in gap junction communication in tenocyte monolayers following an episode of hyperthermia. *The Bone and Joint Journal*, 91-B, Supp. 2, 348.
5. **Davis, J. K., Bishop, P. A., 2013:** Impact of clothing on exercise in the heat. *Sports Med.*, 43, 695—706.
6. **Ely, E. R., Avella, C. S., Price, J. S., Smith, R. K., Wood, J. L., Verheyen, K. L., 2009:** Descriptive epidemiology of fracture, tendon and suspensory ligament injuries in national hunt horses in training. *Equine Vet. J.*, 41, 372—378.
7. **Ely, E. R., Verheyen, L. P., Wood, J. L. N., 2004:** Fractures and tendon injuries in national hunt horses in training in the UK: A pilot study. *Equine Vet. J.*, 36, 365—367.
8. **Hopegood, L., Sander, L., Ellis, A. D., 2013:** The influence of boot design on exercise associated surface temperature of tendons in horses. *Comp. Ex. Phys.*, 9, 147—152.
9. **Hosaka, Y., Ozoe, S., Kirisawa, R., Ueda, H., Takehana, K., Yamaquchi, M., 2006:** Effect of heat on synthesis of gelatinases and pro-inflammatory cytokines in equine tendinocytes. *Biomed. Res.*, 27, 233—241.
10. **Kelechi, T., Michel, Y., Wiserman, J., 2006:** Are infrared thermistor thermometers interchangable for measuring localized skin temperature? *J. Nurs. Meas.*, 41, 19—30.
11. **Mogg, K. C., Pollitt, C. C., 1992:** Hoof and distal limb surface temperature in the normal pony under constant and changing ambient temperatures. *Equine Vet. J.,* 24, 134—139.
12. **Oikawa, M., Kasashima, Y., 2002:** The japanese experiment with tendonitis in racehorses. *Journal of Equine Science*, 13, 41—56.
13. **Smith, R. K. W., Goodship, A. E., 2008:** Tendon and ligament physiology: responses to exercise and training. In **Hinchcliff, K. W., Geor, R. J., Kanep A. J.:** *Equine Exercise Physiology, the Science of Exercise in the Athletic Horse*. Elsevier Ltd, London, 106—131.
14. **Westermann, S., Windsteig, V., Schramel, J. P., Peham, C., 2014:** Effect of a bandage or tendon boot on skin temperature of the metacarpus at rest and after exercise in horses. *Am. J. Vet. Res.*, 75, 375—379.
15. **Williams, R. B., Harkins, L. S., Hammond, J., Wood, J. L. N., 2001:** Racehorse injuries, clinical problems and fatalities recorded on British racecourses from flat racing and national hunt racing during 1996, 1997 and 1998. *Equine Vet. J.*, 33, 478—486.
16. **Wilson, A. M., Goodship, A. E., 1994:** Exercise-induced hyperthermia as a possible mechanism for tendon degeneration. *J. Biomechanics*, 27, 899—905.

Received August 22, 2017

Accepted September 19, 2017