Equine Veterinary Journal

Equine Veterinary Journal ISSN 0425-1644
DOI: 10.1111/evj.12291

Does a magnetic blanket induce changes in muscular blood flow, skin temperature and muscular tension in horses?

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Summary

Reasons for performing study: Static magnetic blankets are often claimed to induce increases in blood flow, reduce muscle tension and tenderness, and be beneficial in both prevention and treatment of musculoskeletal injuries in horses. However, there are no studies that confirm alleged beneficial effects of magnets on muscles of the back in healthy horses.
Objectives: To investigate whether static magnets sewn into a blanket affect back muscle blood flow, skin temperature, mechanical nociceptive threshold (MNT) and behaviour in healthy horses.
Study design: Prospective, randomised, blinded, placebo-controlled crossover study.
Methods: The following outcome measurements of the back of 10 healthy horses were performed; blood flow by photoplethysmography, skin temperature by use of thermistors in conjunction with digital infrared thermography, and MNTs by algometry. The horses' behaviour was filmed during the procedure and scored on an ethogram. Measurements were performed repeatedly for a 30 min baseline period. Thereafter a blanket with active, static magnets (900 gauss) or placebo magnets was placed on the horse and measurements were performed for a 60 min treatment period and a 30 min post treatment period. The study procedure was repeated on the consecutive day, when the horse received the alternative treatment.
Results: Blood flow in muscle, skin temperatures, MNTs and behavioural traits did not differ between active and placebo magnetic blankets. Skin temperature increased similarly during both active and placebo blanket treatment.
Conclusions: In healthy horses, magnetic blankets did not induce additional significant effects on muscle blood flow, skin temperature, MNTs and behaviour when compared with nonmagnetic blankets.

Keywords: horse; static magnet; photoplethysmography; thermography; algometry; behaviour

Introduction

Recently, the number of magnetic products manufactured and promoted for use in animals has increased several-fold. Apart from its use in prevention of disease, common indications for magnetic therapy include muscle soreness, delayed wound healing and pain with a central explanation model of an increased blood flow. A calming effect is sometimes proposed. The effects of magnets on various parameters have been investigated on man [1,2], rats [3,4], mice [5] and rabbits [6], with few equine studies [7–9]. The reported effects of static magnets on blood flow and pain are conflicting [2,4,7,8,10–13], partly due to difficulties in assessing the treatment outcome.

There are few methods available for measurement of intramuscular blood flow that are noninvasive and allow real-time recording without interfering with the study object. The photoplethysmographic (PPG) technique monitors blood flow-related parameters from muscle by use of a light-emitting diode (LED) and a photo detector placed on the skin [14,15]. Indirect data on superficial blood flow may be obtained through measurement of skin temperature, either by use of locally attached thermistors or by digital infrared thermography [16–18]. Changes in muscle tenderness and pain are difficult to assess objectively, and the most common method of assessment is manual palpation. However, compared with palpation, the pressure algometry technique and its measurement of mechanical nociceptive thresholds (MNTs) provides a more objective way of assessing muscle tenderness [19] where horses with a painful condition have lower MNTs than those without pain [20,21]. A possible calming effect of magnets can be assessed by use of ethograms, which register differences in behavioural traits [22,23].

No previous studies have investigated the effect of static magnets on the back of the horse. Thus, the aim of the present study was to investigate the possible clinical effects of static magnets on back muscles in healthy horses by assessing muscle blood flow, skin temperature, MNT and behaviour.

Material and methods

Study design and horses

The study was designed as a prospective, randomised, blinded, placebo-controlled crossover study. Ten horses (4 mares, 5 geldings and one stallion; 9 Standardbred trotters and one Warmblood) with a mean (range) weight of 530 kg (426–680 kg) and a mean age of 13 years (7–20 years) were included in the study. Clinical examination was performed to ensure that the horses did not show initial lameness at trot, did not react positively to palpation of the back, and had a healthy skin and hair coat. The horses' body condition score was 5–6, according to the Henneke scale [24].

Magnetic and placebo blankets

A new, commercially manufactured Beaver nylon magnetic blanket (68% polyester 32% cotton, 145 cm) lined with cotton[a] containing 120 unipolar, ferrous, static magnets (2.5 cm in diameter, 0.4 cm thick; 900 gauss/magnet) was used (Fig 1). The blanket was fitted so that the hind end of the blanket was at the same location on each horse, and the girth tightened to allow 3 finger widths to be inserted under the girth at the ventral midline. The placebo blanket was identical to the active blanket but fitted with demagnetised magnets[a].

Study protocol

In all except one horse, the experiment was performed with the horse tied up in the aisle of its home stable. The remaining horse was, due to anxiety, cross-tied in its stall. Two hours before measurements began, the placebo blanket was placed on the horse and an area of 6 × 13 cm beneath the position of the seventh and eighth magnets in the left row of dorsal magnets was clipped to allow for close contact of the PPG probe onto the

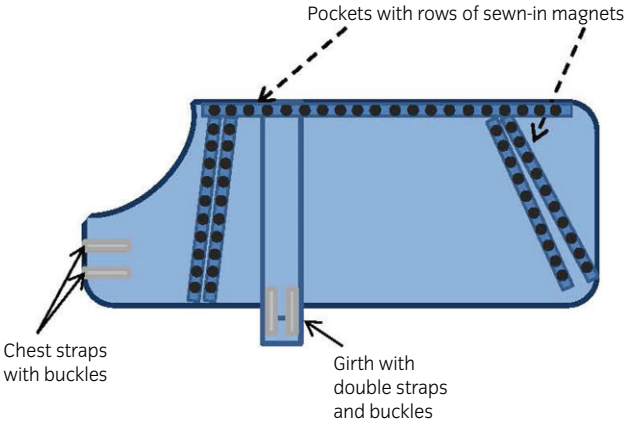

Fig 1: A schematic drawing of the magnetic blanket.

skin. For local skin temperature measurements, an area of approximately 3 × 4 cm was clipped beneath the position of the ninth magnet in the same row of magnets as described above.

The skin thermistors and PPG probe were applied to the clipped skin of the horse and attached with self-adhesive dressing (Fixomull Stretch 2 m × 10 cm)[b]. Baseline thermography was performed and local skin and ambient temperatures were recorded. The spots for algometry were marked and baseline algometry was performed. Thereafter, blood-flow recordings and filming for behavioural assessment were started. After 30 min of baseline recordings, a magnetic blanket[a] or an identical placebo blanket[a] was put on the horse. After 60 min, the blanket was taken off and recordings continued for a 30 min post period. The alternative treatment was performed on the consecutive day and with the horses being tested in the same order.

The order of treatment (active magnet: M, or placebo: P) was assigned to each horse by picking a note from a box. Since active and placebo blankets were identical, the nonblinded author confirmed immediately before putting the blanket on the horse, that the strength of at least 3 randomly chosen magnets was that of the assigned treatment using a gaussmeter (Model 410 Hand-held Gaussmeter)[c]. At the end of the experiment, the magnitude of magnetism at the level of the horses' skin was measured in 3 horses with the gaussmeter carefully introduced under the blanket directly beneath a magnet, and firmly pressed against the skin of the horse. After this, manual pressure was applied to the magnet overlying the gaussmeter. The readings were repeated for at least 10 magnets per blanket.

Outcome measurements

Muscle blood flow: Muscle blood flow was measured using PPG. An optical probe in combination with a board meant for wireless measurement applications was used (Fig 2)[d]. The probe was 64 × 120 mm and consisted of 2 near-infrared (804 nm) LEDs at a centre-to-centre distance of 20 mm from 3 photodetectors. Variations in the AC component of the photodetector signal are related to changes in blood flow in the underlying tissue where the peak-to-peak value is related to changes in both pulsatile blood volume and pulsatile blood flow [25].

Blood flow recordings were performed during predetermined periods; 30–25, 20–15 and 10–0 min before application of the blanket; 10–15, 25–30, 40–45 and 55–60 min during treatment (T15, T30, T45, T60); and 1–5, 10–15 and 25–30 min after treatment (Post+5, Post+15, Post+30). Data were transmitted continuously to a lap-top where the signals were visualised in real-time, in arbitrary units using the computational software MATLAB (2010)[e]. The mean amplitude of pulsations (peak-to-peak value) for 1–2 min of stable recordings was calculated and this value was used for statistical calculations. Only the calculated blood-flow data at the end of the baseline period were used for statistical comparisons and this is denoted as BL-1. Blood-flow data from 30–15 min before application of the blanket were only used to assure that stable blood-flow conditions were established when approaching BL-1.

Temperature: Local skin, as well as in- and outdoor-temperatures, were measured using a 2-channelled thermometer DM 852[f] (measurement range -1 to +50°C; accuracy ±0.1°C). Ambient temperature was measured immediately before and after each study session. Skin temperature was measured 30, 15, and 1 min before application of the blanket (BL-30, BL-15, BL-1); 15, 30, 45, and 60 min during treatment (T15, T30, T45, T60); and 15 and 30 min after the blanket was removed (Post+15, Post+30).

Overall skin temperature was measured using an infrared camera (Iris 7.5 Thermal Imaging System, software WinTES2; accuracy ±0.01°C)[g]. The thermogram was obtained with the camera placed 2.5–3 m behind and levelled above the horse, at an angle of approximately 30° to the vertical plane so that the thermogram covered the croup, back and withers of the horse. The temperature was illustrated with pixels (320 × 240) in different colours. Thermography was performed 35 min (BL-30) and 1 min (BL-1) before application of the blanket, and 1 and 30 min after the blanket was taken off (Post+1 and Post+30).

Pressure algometry technique: Measurements of MNT were conducted in triplicate with a pressure algometer[h] at 3 locations along the right side of the vertebral column (10 cm dorsal to C4-5, and 5 cm lateral of Th8-9 and L1-2). The measurements were performed 35 min before application of the blanket (BL-30), and at Post+5 and Post+30, and the reading of the MNTs was made by a separate investigator. Algometry calibration was performed by measuring a brass standard of known weight, supplied by the manufacturer of the algometer[h], at the beginning and end of each day of the study period.

Behavioural assessment: Each trial was videotaped with the camera placed approximately 2 m in front of and 1 m lateral to the horse (with the exception of one horse that was videotaped from behind, at an angle to allow visualisation of tongue movements). Two different ethograms were used to evaluate the behaviour of the horse from the video recording. In one protocol the horses' type of behaviour was evaluated and registered every 10 min; starting at BL-30 and ending at Post+30. In the other

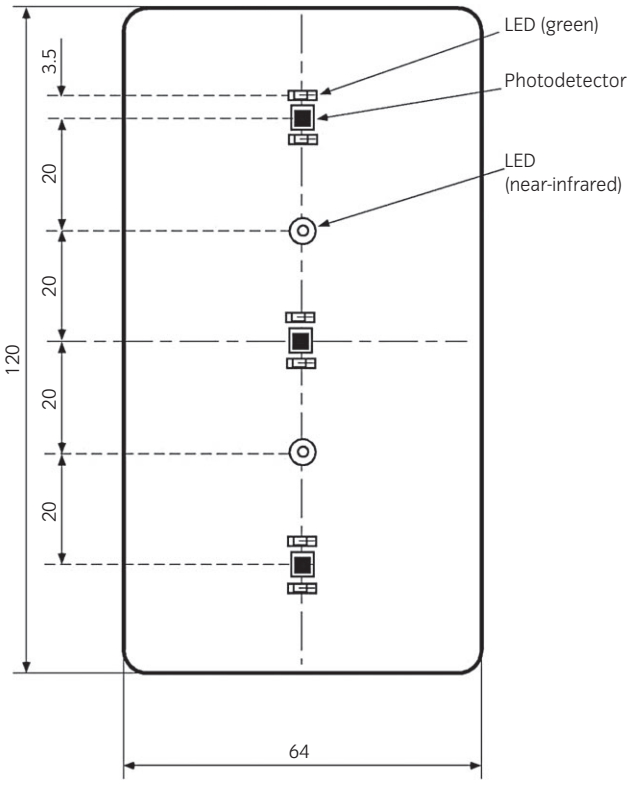

Fig 2: A schematic drawing of the photoplethysmography probe. Measurements are in mm. LED = light-emitting diode.

protocol the frequency of a number of behavioural traits was registered during a 4 min period before the blanket was applied and during the last 4 min with the blanket on. The registered traits were: general appearance (alert-drowsy), movement of legs (changing weight, moving, scraping the floor with front hoof, kicks), movements of the head and neck (lifting, lowering, shaking or nodding) and other (ear and tongue movements, snorting, neighing, sighing, chewing, biting in cross-ties and yawning).

Data analysis

Descriptive statistics (mean ± s.d.) were performed in Microsoft Office Excel 2007[i]. Statistical analysis of changes over time and between groups was performed using ANOVA in Statistica10[j] followed by Tukey's *post hoc* test where appropriate. Wilcoxon test and Spearman's correlation test (SAS)[k] were used to compare behavioural traits. Treatment effects on behavioural traits were examined by comparing the mean values for the period before the blanket was adapted to the horse (BL-30, -20 and -10) with the mean values for the entire period with the blanket on the horse (T10, 20, 30, 40, 50, 60) using a Student paired *t* test in Microsoft Office Excel 2007[i].Treatment effects on MNTs were examined by comparing BL-1 with Post+5 and Post+30, and comparing Post+5 with Post+30 using a Student's paired *t* test in Microsoft Office Excel 2007[i].

Values for blood-flow recordings were noted as a percentage change compared with the perfusion at BL-1, which was regarded as baseline. These values were also used for statistical comparisons. Each thermogram was subjectively evaluated with regard to the degree of symmetry and localisation of maximal temperature. The maximal temperature (within the area of the blanket) on each thermogram was recorded. For statistical comparison of temperature measurements, the delta values as compared with the temperature obtained at BL-1 were used.

Statistical significance was accepted when $P<0.05$.

Results

Blood flow

Only paired blood-flow measurements were included in statistical analysis. Results are presented for 6 horses. In 2 horses, blood-flow measurements were disturbed by motion artefacts caused by breathing or movement. No signal at all was obtained in 2 horses due to very heavy skin pigmentation. There were no statistical differences within groups over time, and there was great individual variation in response to application of either blanket. A significant overall difference ($P = 0.02$) between groups was seen, but not when comparing each time point (Fig 3).

Ambient and local skin temperature measurements

The mean ambient temperature difference between Day 1 and Day 2 was 0.1 ± 2.0°C, and between placebo and active magnet treatment was 0.7 ± 1.9°C. Baseline skin temperature are presented for 9 horses and, from BL-30 until BL-1, temperatures were stable and did not differ between groups. In both groups, skin temperature was significantly increased at all time points during treatment (T15–T60) compared with before treatment (BL-1), with an overall time effect of $P<0.001$ but with no differences between groups ($P = 0.6$; Fig 4). Local skin temperature had returned to baseline values 15 min after blanket removal in both groups.

Thermography

Results are presented for 7 horses. Data from 3 horses are missing due to technical problems. There were no significant differences in maximum temperature between treatment groups at any time point. In both groups, the maximum temperature at Post+1 was higher than that at BL-1 and Post+30 (Group magnet (M), $P = 0.02$; Group placebo (P), $P = 0.05$).

With subjective assessment, a clear pattern showing areas of increased temperature coinciding with the placement of magnets ('magnet-pattern') was recognised in 4 thermograms at Post+1 (Fig 5). Three of these thermograms were from horses wearing the placebo blanket. A weak 'magnet-pattern' was seen at Post+1 in 2 thermograms each after active and placebo magnetic treatment. By Post+30, 10 out of 18 thermograms were almost identical to the thermograms obtained at BL-1, 6 thermograms showed still slightly increased (2 Group M; 4 Group P) and 2 slightly decreased (Group M) temperatures.

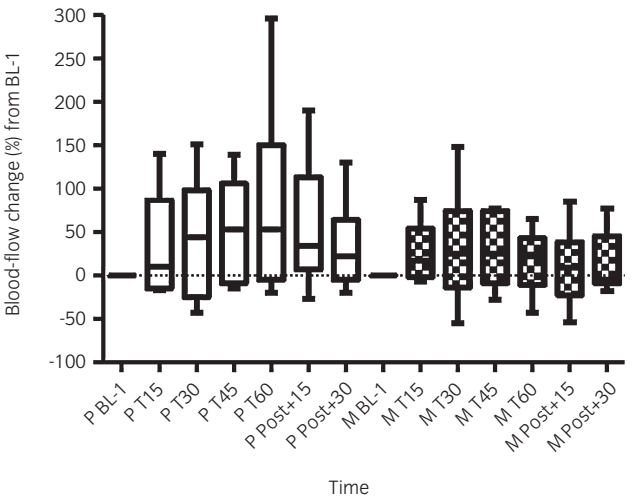

Fig 3: Box-and-whisker plots showing changes (%) in local muscle blood flow, measured by photoplethysmography, from 1 min before the blanket was put on the horse (BL-1); at 15, 30, 45 and 60 min while the blanket was on (T15, T30, T45 and T60); and at 15 and 30 min after the blanket was removed (Post+15 and Post+30). White boxes = placebo (P) blanket (n = 6); spotted boxes = active magnetic (M) blanket (n = 6). Each box represents the interquartile range. The horizontal line is the median. The upper and lower whiskers represent maximum and minimum values. Blood flow was not different between groups at any specific time point, and did not change over time.

Pressure algometry

The results are presented for 8 of the 10 horses, since 2 horses could not be measured due to technical problems. For the horses wearing the active magnetic blankets the mean and s.d. values were: BL-30, 856 ± 202, Post+5, 807 ± 104 and Post+30, 883 ± 195 kPa, and for those wearing the placebo blanket: BL-30, 880 ± 285, Post+5, 854 ± 256 and Post+30, 887 ± 173 kPa.

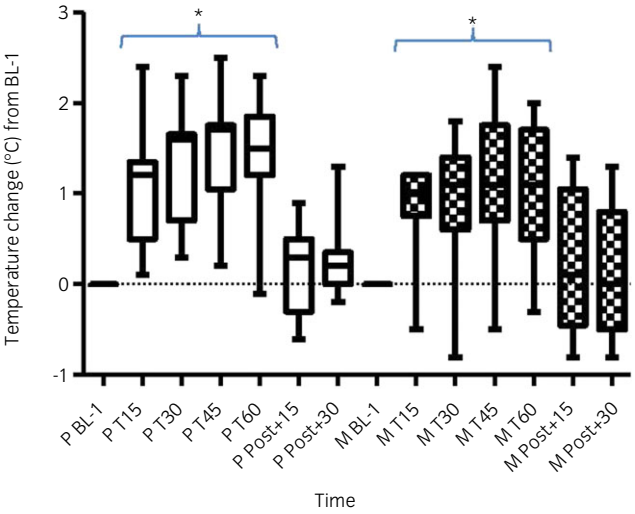

Fig 4: Box-and-whisker plots showing changes in local skin temperature from 1 min before the blanket was put on the horse (BL-1); at 15, 30, 45 and 60 min while the blanket was on (T15, T30, T45 and T60); and at 15 and 30 min after the blanket was removed (Post+15 and Post+30). White boxes = placebo (P) blanket (n = 9); spotted boxes = active magnetic (M) blanket (n = 9). Each box represents the interquartile range. The horizontal line is the median. The upper and lower whiskers represent maximum and minimum values. *denotes a significant difference ($P<0.05$) within each group compared to BL-1. There was no difference between groups.

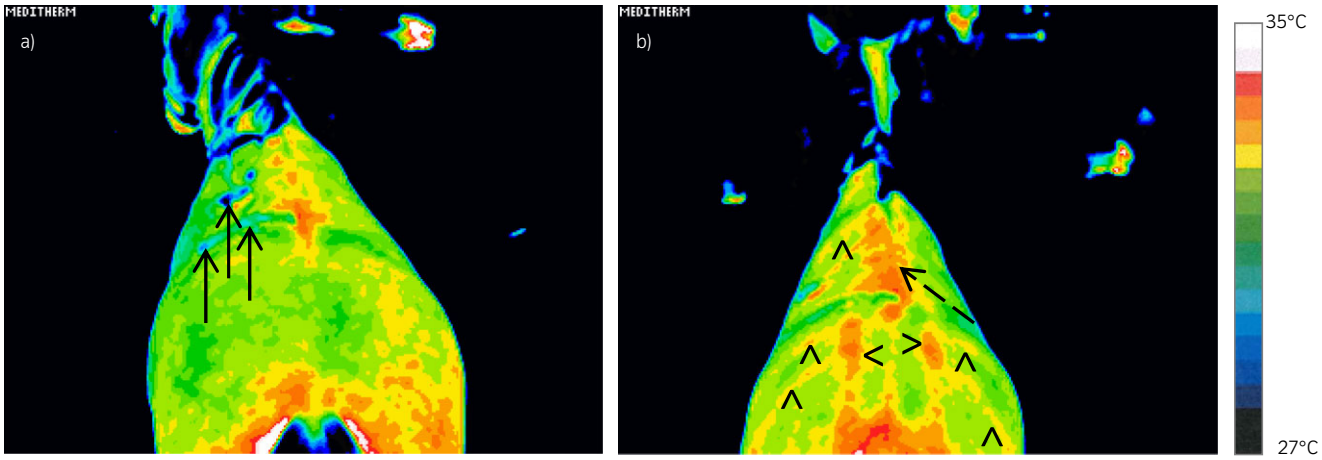

Fig 5: a) A thermogram of a horse before application of the blanket. Arrows show areas of decreased temperature where the photoplethysmography probe and transmitter are attached to the horse. b) The same horse 1 min after removal of the placebo blanket. Arrowheads show increased temperature in areas previously covered by (placebo) magnets. The broken arrow shows a widened area of increased temperature along the midline. The temperature scale in °C is shown to the right of Fig 5b.

There were no significant differences in MNTs between the 3 soft tissue locations, nor between or within groups for any of the measurement locations.

Behavioural studies

The results are available for 7 of the 10 horses since 3 horses were not filmed. There was a significant increase in the values for 'General appearance' from before treatment (BL-30–BL-10) to during treatment (T10–T60), in both treatment groups (magnet +0.5, placebo +0.4, P = 0.01), but there were no significant differences in behavioural traits between treatments, in either behavioural protocol.

Magnetism

The readings of the magnetic strength on the active blanket fluctuated between 400 and 900 Gauss, and below 20 Gauss for the placebo blanket. The measured magnitude of magnetism at the level of the skin of 3 horses, directly underneath an active magnet, varied between 20–250 gauss. When applying manual pressure to the blanket and magnet, the readings increased to approximately 300–400 gauss; 900 gauss was never reached.

Discussion

The study did not detect any differences between healthy horses treated with a blanket with active static or placebo magnets in regard to skin temperature, MNTs or behavioural traits, nor any major differences in muscle blood flow. The small difference in blood flow between groups that was detected disappeared (P = 0.8) when removing the values of one horse, which had great impact on the mean values of the placebo group. The great individual variation regarding blood-flow change indicate that static magnets did not have a significant uniform impact on blood flow.

The results of previous studies on the effect of static magnets on blood flow in man and laboratory animals are inconsistent, some reporting decreases [4,26] while others describe increases [6] or no effect [27]. In these studies, skin blood flow was investigated with various methods. Only one study reports the effect on muscle blood flow [5]. In that study, blood flow in the *tibialis* muscle of anaesthetised mice increased after application of a static magnetic field of 10 and 100, but not after 3 Gauss. There are only 2 previous studies on the effect of static magnets compared with placebo on blood flow in horses. Kobluk *et al*. [7] reported significant increases in blood flow in soft tissues and bone using scintigraphy after application of a magnetic pad (600 gauss) to the metacarpus. Conversely, a similar study using scintigraphy did not show any significant differences in relative perfusion ratio after application of a magnetic wrap (270 gauss) to the metacarpus [8]. The strength of the static magnet may be of importance for the outcome [3,5] and a field intensity of 1 mT (10 gauss) has been suggested as a threshold level [5,12]. The magnitude of the static magnet field is dependent on the distance between the magnet and the target. Steyn *et al*. [8] reported that the magnetic field 7 mm from the surface of a magnet of 270 gauss decreased to 0.5 gauss. The distance between the magnet and target tissue could possibly explain the lack of influence on muscle blood flow in the present study. Even when external pressure was applied to a magnet, the magnitude close to the horse's skin never exceeded 400 gauss. Since, during the trial, the PPG probe was placed between a magnet and the skin of the horse; this of course further increased the distance. However, temperature measurements did not reveal any differences between active and placebo treatment. It has also been suggested that the magnet-induced alteration in microcirculation depends on the initial vessel tone, indicating that the effect may vary depending on the condition of the treated tissue [3,28]. It is possible that recordings of blood flow would have yielded other results in horses with an altered vascular tone such as during anaesthesia or in the presence of certain pathologic conditions.

This is the first study that presents results from the noninvasive PPG technique in horses. The ability to record muscle blood flow in man was demonstrated by simultaneous invasive measurement of blood flow (fibre tip inserted into muscle) using laser Doppler flowmetry and noninvasive measurement of blood flow using PPG while artificially manipulating muscle blood flow [15]. After static and dynamic muscle contractions muscle blood flow measured by PPG and near-infrared light increased, but not skin blood flow measured by PPG and green light [14]. The increase in the *tibialis anterior* muscle blood flow was also verified by measurement of blood flow in the femoral artery using ultrasound Doppler [14]. More recently it has been shown that different geometries of a PPG probe in combination with near-infrared and green light may discriminate between blood flow at different vascular depths [29,30]. A measuring depth of > 23 mm was observed for a similar probe as used in this study. The PPG technique we used did not yield any signals in horses with heavy skin pigmentation making the technique of limited use in dark horses. Another problem when using optical methods for measuring physiological parameters is motion artefacts [31,32]. Apart from these technical limitations, PPG has great potential in future research as a noninvasive means of measuring intramuscular blood flow.

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 [16,33]. The increased skin temperature during treatment with either blanket is mainly explained by the insulation effect of the blanket [34]. A similar result was obtained by Turner *et al*. [9] who found no difference in the temperature increase, as measured with thermography, after a 24 h application of a wrap containing a biomagnet compared with a placebo wrap. In the present study, local skin

temperature had returned to pretreatment levels already 15 min after removal of the blanket, indicating that no further residual effect of wearing the active magnetic blanket compared with placebo was present. The thermal pattern seen in some thermograms at Post+1 (Fig 5), showing increased heat under both active and inactive magnets, indicates an additional insulatory effect by the 'magnets' themselves. This pattern was most obvious over the croup of the horse indicating that the blanket and 'magnets' were in closer contact with the skin in this area. Due to the very small differences in ambient temperature between study days and in the body condition scoring between horses, it is unlikely that these parameters had any influence on the results.

It is hypothesised that a high tissue temperature reduces muscle tension through an influence on muscle spindles [35]. It is unlikely that the small temperature increase seen in the present study would cause an increased muscle relaxation [35]. This is supported by the algometry data, which show no differences in MNTs between groups. In contrast, other interventions aiming at reducing muscle tension, have resulted in significant differences in MNT values [36,37].

Static magnets are claimed to have a calming effect. The use of a behavioural protocol offers an objective way of assessing maintenance behaviour [23]. There were 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 possibly also be an effect of time. The use of 2 different protocols to assess behaviour somewhat reduced the risk of a false negative result [22]. It is possible that measurements of MNTs and behaviour would have differed more in horses with clinical back pain.

Finally, the results from the present study reporting increases in muscle blood flow and local skin temperature during treatment with both active and placebo blankets emphasise the importance of a true placebo treatment and blinding in these types of studies.

Conclusion

In healthy horses, static magnetic blankets did not have significant effects on muscle blood flow, skin temperature, MNTs of the epaxial muscles and behaviour as compared with a placebo blanket. Further studies are needed to investigate whether any effect may exist in horses with increased muscle tension and tenderness.

Authors' declaration of interests

MagnetHealth AB provided the magnetic and placebo magnets but did not provide any funding for completion of the study or have any influence on the design or conclusions of the study.

Ethical animal research

The experimental procedure was approved by the local Ethical Committee on Animal Experiments in Uppsala, Sweden.

Source of funding

SLU scholarships for researchers (Linnea and Axel Ericsson's stipendiefond) and veterinary students.

Acknowledgements

The authors wish to express their sincere gratitude to SLU for financial support, to the veterinary students Gustaf Elsing and Josefine Blennersjö for their role in executing parts of the study, to technical staff at the Department of Clinical Sciences and at the Veterinary Institute for technical assistance with the horses and Magnetic Health AB for providing magnetic and placebo blankets.

Authorship

A. Edner and A. Bergh were responsible for the study design and the study execution, parts of data collection and data analysis and interpretation, and they prepared most of the manuscript. L.-G. Lindberg was responsible for the PPG probe and all PPG analysis and interpretation. H. Broström was responsible for thermography. All authors contributed to the manuscript.

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[i]Microsoft, Redmond, Washington, USA.
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