

Effect of defocused CO₂ laser on equine skin, subcutis and fetlock joint temperature

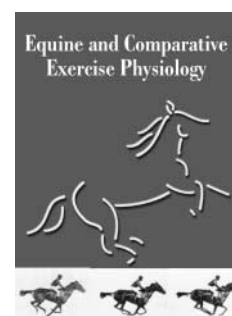
Anna Bergh^{1,*}, Görel Nyman², Thomas Lundeborg³ and Stig Drevemo¹

¹Department of Anatomy and Physiology, Swedish University of Agricultural Sciences, SE-75007 Uppsala, Sweden

²Department of Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden

³Department of Physiology and Pharmacology, Karolinska Institute, Stockholm, Sweden

*Corresponding author: Anna.Bergh@afys.slu.se



Submitted 21 July 2004; Accepted 8 December 2004

Research paper

Abstract

Despite the increasing use of lasers in the rehabilitation of horses, the biophysical action of the laser is not clearly defined. The purpose of this study was to determine the effect of a defocused CO₂ laser on the temperature of the skin, subcutis and fetlock joint in standing and anaesthetized horses. A cross-over design comprising 10 standing horses was used. Consecutive irradiation (91 J cm⁻²) was applied to each of the three aspects of the front fetlock joint of these animals. In 12 anaesthetized horses (eight laser-treated and four control), irradiation (137 J cm⁻¹) was applied to the dorsal side of the joint. In the standing group, skin temperature increased on average by 5.3°C to 34.8 ± 1.5°C (*P* < 0.05) and the subcutis temperature increased by 5.7°C to a mean temperature of 36.0 ± 0.9°C during laser treatment. There was no difference in joint temperature between laser-treated and control horses. Similar results were obtained in anaesthetized horses. Treatment with a defocused CO₂ laser caused a significant increase in the temperature of the skin and subcutis, but not in the joint cavity. Further studies are needed to investigate if the increase in temperature influences perfusion and modulation of pain, as a result of defocused CO₂ laser treatment.

Keywords: defocused CO₂ laser; horses; laser therapy; thermal effect; rehabilitation

Introduction

The use of physical therapy is a rapidly growing field in horse rehabilitation. One modality that has gained interest is the laser. It is used, in both humans and animals, in the treatment of a variety of injuries such as wounds, tendonitis, back problems and osteoarticular diseases^{1–4}. Relatively few studies describe the outcome of these treatments. However, results from a recent study indicate that a defocused carbon dioxide (CO₂) laser may be an applicable treatment for acute synovitis in horses⁵.

The effect of laser radiation on tissue structures and function remains unclear. The CO₂ laser is proposed to produce photochemical and photomechanical, as well as thermal effects⁶. These photothermal effects result from the transformation of absorbed light energy

to heat⁷. It has been suggested that thermal effects initiate pain relief, increase tissue perfusion and reduce muscle spasms, explanations shared with other thermal modalities used in physical rehabilitation^{8–13}.

The goal of physical therapy is to promote the healing of tissues through the stimulation of normal physical processes, thereby restoring the function of injured tissues¹⁴. Physical therapy makes a distinction between ranges of temperatures considered to have a beneficial influence on human tissue. Therapeutic effects are expected in the approximate temperature range 40 to 45°C¹⁵. In addition, the therapeutic effects are also dependent on the increase in heat and the area heated. Based on earlier studies on human muscles, an increase of 1°C (mild heating) accelerates the

metabolic rate in tissues¹⁶. An increase of 2–4°C (moderate heating) reduces muscle spasm, pain and chronic inflammation, and increases blood flow, while vigorous heat ($\geq 4^\circ\text{C}$) decreases the viscoelastic properties of collagen and inhibits sympathetic activity^{17,18}. Extreme temperatures above 45°C may cause thermal pain and injury to tissues¹⁶. Repeated exposures, individually incapable of causing recognizable epidermal injury, may have the same total destructive capacity as a single exposure of longer duration¹⁹.

Intra-articular temperature is suggested to increase by deep-heat treatments such as therapeutic ultrasound and decrease by superficially applied hot packs. Contrary to this, results from studies on humans with arthritis indicate that the intra-articular temperature is increased by superficial heat^{20–22} and the general consensus is that superficial heat may aggravate symptoms in acute inflammatory arthritis²⁰.

The activity of cartilage-degrading enzymes in human rheumatoid arthritis and active osteoarthritis is influenced by local joint temperature. The destruction of articular cartilage by collagenase is shown to be significant at 37°C and very low at 32°C^{23,24}. Therefore, treatments that elevate intra-articular temperature, such as superficial heat and ultrasound treatment, are unsuitable for treating active arthritis or secondary synovitis in osteoarthritis²².

When designing a rehabilitation programme with a thermal modality such as the defocused CO₂ laser, it is important to predict both benefits and risks of the thermal exposure. The aim of the present study was to investigate the effects of defocused CO₂ laser treatment on temperature in the skin, subcutis and fetlock joint in the horse. The hypothesis was that laser treatment would result in an increase in temperature in the skin, subcutis and fetlock joint. Further, a more pronounced temperature increase was expected in skin that had an unclipped hair coat, compared with clipped.

Materials and methods

Laser equipment

A defocused CO₂ laser (KSV 25S; EL.EN. Srl, Florence, Italy) was used in the study. The HeNe source emitted continuously at 1.2 mW. The laser was calibrated regularly, and an external detector (LaserMate Detector, COA-33-0191-000; Gamma Optronics AB, Uppsala, Sweden) was used to measure the output effect before and after each treatment.

Temperature protocol

The temperature in the skin, subcutis and fetlock joint was measured using a thermistor with a range between –1 and +50°C (DM852; ELLAB, Rødovre, Denmark). A flexible probe 0.8 mm in diameter

(MAA-08 500-A; ELLAB) was inserted 3–4 cm into the fetlock joint, from the lateral aspect. A needle probe measuring 0.8 mm in diameter (MKA-08 050-A; ELLAB) was inserted approximately 15 mm under the skin, in the midline of the dorsal side of the fetlock joint and 2 cm proximal to the treatment area. A skin probe (MHB-08 025-A; ELLAB) was attached with adhesive tape over the midline, 2 cm proximal to the treatment area. After each treatment occasion, the thermistor and the probes were controlled in a water bath using a mercury thermometer.

Horses, experimental environment and experimental design

The experimental protocol consisted of one study on standing horses and three studies on anaesthetized horses. The experiments were approved by the Ethical Committee on Animal Experiments in Uppsala, Sweden.

Standing horses

Ten healthy Standardbred trotters (four females and six geldings) with a mean weight of 489 kg (range 403–580 kg) and a mean age of 7 years (range 3–13 years) were used in the study.

The experiment was designed as a cross-over study with randomized laser and control treatments (with no laser output). On each treatment occasion, body temperature was measured and a blood sample was drawn from the jugular vein. An area of 6 cm × 7 cm on the lateral, dorsal and medial sides of the fetlock joint was washed with antiseptic solutions (Hibiscrub®, Hibitan®; Zeneca, Göteborg, Sweden). Approximately 20 min was allowed between the antiseptic wash and the start of the procedure.

Consecutive irradiations of 91 J cm⁻² (16 W) were applied at a distance of 1 m on the lateral, dorsal and medial aspects of the fetlock joint for 4 min, respectively. Temperature was measured at 30-s intervals; from 5 min before the start of the treatment, during the treatment and for 5 min after the end of the treatment.

Anaesthetized horses

This first study on anaesthetized horses consisted of 12 healthy Standardbred trotters (11 females and one gelding) with a mean weight of 501 kg (range 375–580 kg) and a mean age of 7 years (range 2–20 years). Eight horses received laser treatment and four served as controls.

Laser-treated and control groups were randomized. Body temperature was measured and a blood sample was drawn from the jugular vein. The horses were anaesthetized according to two different protocols; animals were pre-medicated with either acepromazine (Plegicil® vet.; Pharmacia Upjohn Animal Health,

Helsingborg, Sweden) and methadone (Metadon[®]; Pharmacia & Upjohn: P&U, Stockholm, Sweden) or with detomidin (Domosedan[®] vet.; Orion Pharma, Finland). Anaesthesia was induced intravenously with guaifenesin (Myolaxin[®] vet. diluted to 7.5%; Chassot & Cie AG, Switzerland) and thiopentone (Pentothal[®] natrium 12.5%; Abbott, Solna, Sweden). The horses were intubated, transported to the surgical table and placed in left lateral recumbency. The non-dependent forelimb, which was used for treatment, was supported in a position perpendicular to the body axis. Anaesthesia was maintained with either halothane (Fluotane[®]; Astra, Södertälje, Sweden) or isoflurane (Forene[®]; Abbott) in oxygen. An electrolyte solution (Ringer acetate; Pharmacia & Upjohn: P&U) was continuously infused through a catheter in the left jugular vein. Spontaneous breathing was allowed from a semi-closed, large-animal circle.

The treatment area (6 cm × 7 cm) on the dorsal side of the fetlock joint area was washed with an antiseptic solution and the temperature probes were introduced as described above after synovia had been sampled.

The irradiation energy was 137 J cm⁻² (16 W, 6 min) and the temperature was measured at the similar intervals as in the standing horse, from 5 min before start of the treatment, during the treatment and until 30 min after the end of treatment (recordings were carried out every minute from 10 min after end of treatment).

Study on temperature in clipped and unclipped hair coat (clipped/unclipped)

A second experiment was performed on seven of the anaesthetized horses described earlier, four females and three geldings, with a mean weight of 464 kg (range 375–548 kg) and a mean age of 9 years (range 2–24 years). The experiment was designed as a cross-over study and the two treatments, laser on clipped and unclipped skin, were randomized. A treatment area (6 cm × 7 cm) over each gluteal muscle was prepared; one part clipped and one with the hair coat intact. A small area for the measuring probes, in direct contact with the treatment area, was also clipped and surgically prepared, and a skin temperature probe and a probe inserted subcutaneously were attached. The irradiation energy was 171 J cm⁻² (20 W, 6 min) and the temperature was measured at the same intervals as in the standing horse: from 5 min before start of the treatment, during the treatment and until 5 min after the end of treatment.

Extended study on fetlock temperature during anaesthesia (extended study)

The third study comprised six, healthy Standardbred trotters (four females and two geldings) with a mean weight of 483 kg (range 460–507 kg) and a mean age of 8 years (range 5–13 years). Four horses received laser

treatment and two served as controls. The laser-treated and control groups were randomized. The procedure was similar to the protocol used in the anaesthetized group except that all horses were pre-medicated with detomidin (Domosedan[®] vet.; Orion Pharma), placed in dorsal recumbency, and that anaesthesia was maintained with isoflurane (Forene[®]; Abbott) in oxygen. An output power of 16 W for 4 min (irradiation energy of 91 J cm⁻²) on the dorsal side of the fetlock joint was used. The treatment protocol started when the temperature had reached a steady state, and ended when a new steady state was observed after treatment. Steady state was defined as 10 min of stable temperature ($\pm 0.1^{\circ}\text{C}$). The temperature of the joint was recorded every minute, during the 4 min of treatment and continued until steady state after treatment.

Statistical analysis

For data analysis, Statistica 6.0 (Statsoft, 2001; Statsoft Scandinavia AB, Uppsala, Sweden) was used and results are presented as mean $\pm$ standard error. Statistical significance was accepted at $P < 0.05$. The intention of the study was to describe the total heating effect during a specific time period from a relatively small amount of experimental material, i.e. the cumulative response to the intervention. Therefore, the method 'area under curve' was selected.

Before the statistical calculations, the data were individually corrected by subtracting the mean for each individual pre-treatment period. The area under the curve for the total treatment period, as well as for each treatment projection itself (i.e. lateral, dorsal and medial projection), was calculated. Wilcoxon matched pairs signed rank sum and Mann-Whitney tests were used where appropriate.

Results

Standing horses

The temperature response to laser treatment is shown in Table 1. The results presented for skin and fetlock joint temperatures are from nine horses, since the results from the measurements of one horse had to be excluded due to failure of the temperature probe (Fig. 1).

The temperature response in the skin is illustrated in Fig. 2a. The increase in temperature was significantly higher during laser treatment compared with the controls. The maximum temperature was reached in the dorsal projection during treatment, followed by a decline towards the baseline level. The average increase, measured during treatment from the dorsal side, was $5.3 \pm 1.4^{\circ}\text{C}$ and $0.5 \pm 0.5^{\circ}\text{C}$ for the laser treatments and controls, respectively.

In seven of the nine horses that received laser treatment, the temperatures did not return to the respective pre-treatment baseline at 5 min after treatment.

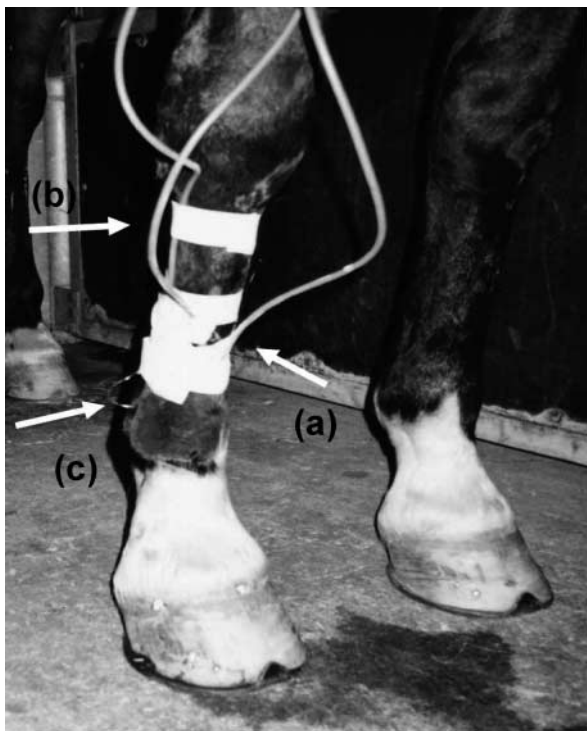
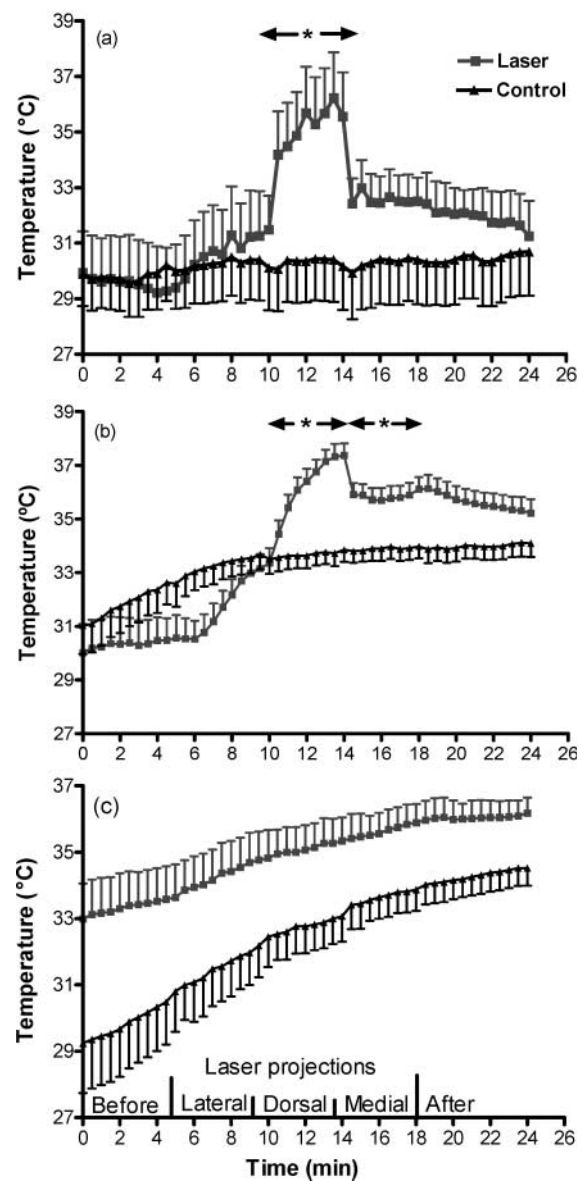
Table 1 Mean $\pm$ standard error of temperature variables ($^{\circ}\text{C}$) in standing horses during laser treatment. The treatment was applied to three projections: lateral, dorsal and medial. Total treatment represents the mean value of the whole treatment period

	Pre-treatment	Treatment				Post-treatment
		Lateral projection	Dorsal projection	Medial projection	Total treatment	
Skin ($n = 9$)						
Laser	29.5 $\pm$ 1.6	30.7 $\pm$ 1.6	34.8 $\pm$ 1.5*	32.5 $\pm$ 0.9	32.7 $\pm$ 1.4*	31.9 $\pm$ 1.1
Control	29.8 $\pm$ 1.1	30.3 $\pm$ 1.4	30.3 $\pm$ 1.5	30.3 $\pm$ 1.6	30.3 $\pm$ 1.4	30.5 $\pm$ 1.6
Subcutis ($n = 10$)						
Laser	30.3 $\pm$ 1.4	31.7 $\pm$ 1.2	36.0 $\pm$ 0.9*	35.9 $\pm$ 0.2*	34.6 $\pm$ 1.1*	35.6 $\pm$ 0.1
Control	31.9 $\pm$ 0.9	33.3 $\pm$ 0.6	33.7 $\pm$ 0.5	33.9 $\pm$ 0.4	33.6 $\pm$ 0.6	34.0 $\pm$ 0.5
Fetlock joint ($n = 9$)						
Laser	33.3 $\pm$ 1.0	34.3 $\pm$ 0.9	35.1 $\pm$ 0.7	35.7 $\pm$ 0.6	35.0 $\pm$ 0.7	36.0 $\pm$ 0.5
Control	29.9 $\pm$ 1.4	31.6 $\pm$ 1.0	32.8 $\pm$ 0.8	33.7 $\pm$ 0.6	32.7 $\pm$ 0.9	34.3 $\pm$ 0.5

*Significantly different from control group ($P < 0.05$).

The temperature response in the subcutis is illustrated in Fig. 2b. The increase in temperature was significantly higher during the total laser treatment compared with the controls. The average increase measured during treatment from the dorsal aspect was $5.7 \pm 1.0^{\circ}\text{C}$ and $1.8 \pm 0.7^{\circ}\text{C}$ for laser treatments and controls, respectively. In all horses that received laser treatment, the temperature did not return to the respective pre-treatment baseline at 5 min after the treatment.

The temperature in the fetlock joint increased during both laser treatment and in the controls ($1.8 \pm 0.4^{\circ}\text{C}$ and $2.9 \pm 0.7^{\circ}\text{C}$, respectively) (Fig. 2c). No significant differences in temperature were observed between irradiated and control joints.

**Fig. 1** Placement of the temperature probes to the (a) skin, (b) subcutis and (c) fetlock joint**Fig. 2** Temperature in standing horses during laser treatment: (a) skin, $n = 9$; (b) subcutis, $n = 10$; (c) intra-articular, $n = 9$. The treatment was applied to three projections: Lateral, dorsal and medial. Values are expressed as mean $\pm$ SE for the two groups, laser and control. *Significantly different from control group ($P < 0.05$)

The temperature did not return to the baseline during the experimental session.

Anaesthetized horses

The temperature response is shown in Table 2. The results presented for the skin temperature are based on data from seven treated horses and four controls.

The temperature response in the skin is shown in Fig. 3a. The increase in temperature was significantly higher during the laser treatment compared with the controls ($3.2 \pm 0.7^\circ\text{C}$ and $0.0 \pm 0.2^\circ\text{C}$, respectively). There was a significant difference in temperature during the 5-min period after treatment ($2.2 \pm 0.5^\circ\text{C}$ and $0.3 \pm 0.0^\circ\text{C}$, respectively). In five of the seven horses that received laser treatment, the temperature had not returned to the respective pre-treatment baseline at 30 min after treatment.

The temperature response in the subcutis is summarized in Fig. 3b. The increase in temperature was significantly higher during the laser treatment than in the controls ($5.5 \pm 1.4^\circ\text{C}$ and $-0.2 \pm 0.4^\circ\text{C}$, respectively). There was a significant difference in temperature during both the 5-min period ($2.9 \pm 0.8^\circ\text{C}$ and $0.1 \pm 0.3^\circ\text{C}$, respectively) and the 10-min period ($1.7 \pm 0.5^\circ\text{C}$ and $0.3 \pm 0.1^\circ\text{C}$, respectively) after treatment. In seven of the eight horses that received laser treatment, the temperature had not returned to the respective pre-treatment baseline at 30 min after treatment.

The temperature in the fetlock joint was not affected by laser treatment ($0.1 \pm 0.0^\circ\text{C}$ and $0.1 \pm 0.0^\circ\text{C}$ for the laser-treated and control groups, respectively). In addition, the temperature in the fetlock joint was unaffected in both laser-treated and control groups ($-0.1 \pm 0.0^\circ\text{C}$ and $0.0 \pm 0.1^\circ\text{C}$, respectively) in the extended study. No significant differences in temperature were observed between the laser-treated and control groups.

The results presented for skin and subcutis temperatures in the clipped/unclipped condition are from five and six horses, respectively, since results from the measurements of one horse had to be excluded due to technical problems (Fig. 4). A significant difference in skin temperature between clipped and unclipped areas ($5.2 \pm 1.4^\circ\text{C}$ and $11.3 \pm 2.6^\circ\text{C}$, respectively) was found, as shown in Table 3 and Fig. 4. There were no differences in the post-treatment period. No significant differences in the temperature of the subcutis were observed between clipped and unclipped areas.

Discussion

The present study shows significantly higher skin and subcutis temperatures after defocused CO₂ laser treatment compared with controls, in both standing and anaesthetized horses. However, no significant differences were observed in the fetlock joint temperature. To the best of our knowledge, no study has been performed on the thermal effects of defocused CO₂ laser treatment in horses. Therefore, comparison can only be made with studies on other modalities with a thermal effect.

Methodology

The study was performed on standing horses to mimic a true treatment procedure, with all physiological regulatory systems intact. The insertion of the thermistor into the fetlock joint was made through a needle. Although this method is well documented²⁵, it is likely that the mechanical effect of the thermistor itself may have affected the joint temperature. Therefore, to avoid voluntary movement of the horse, one part of the study was performed on anaesthetized horses, taking into account the fact that general anaesthesia and positioning affect the temperature and perfusion^{26,27}.

Table 2 Mean $\pm$ standard error of temperature variables ($^\circ\text{C}$) in anaesthetized horses during laser treatment. The treatment was applied to the dorsal projection only

			Post-treatment period (min)					
	Pre-treatment	Treatment	0–5	6–10	11–15	16–20	21–25	26–30
Skin (<i>n</i> = 11)								
Laser	30.2 ± 0.4	33.5 ± 0.9*	32.3 ± 0.5*	31.8 ± 0.5	31.7 ± 0.5	31.7 ± 0.6	31.8 ± 0.6	31.8 ± 0.6
Control	30.3 ± 1.1	30.3 ± 1.2	30.7 ± 1.1	31.0 ± 1.1	31.2 ± 1.0	31.4 ± 1.0	31.5 ± 1.0	31.6 ± 0.9
Subcutis (<i>n</i> = 12)								
Laser	31.9 ± 0.4	37.4 ± 1.4*	34.8 ± 0.6*	33.6 ± 0.5*	33.4 ± 0.5	33.3 ± 0.6	33.2 ± 0.6	33.2 ± 0.6
Control	31.2 ± 1.3	31.0 ± 1.5	31.2 ± 1.5	31.5 ± 1.4	31.7 ± 1.4	31.9 ± 1.4	32.0 ± 1.3	32.0 ± 1.3
Fetlock joint (<i>n</i> = 12)								
Laser	33.3 ± 0.6	33.4 ± 0.6	33.7 ± 0.5	33.9 ± 0.6	33.9 ± 0.6	33.8 ± 0.7	33.8 ± 0.7	33.7 ± 0.7
Control	34.1 ± 0.7	34.2 ± 0.8	34.4 ± 0.8	34.5 ± 0.8	34.6 ± 0.7	34.7 ± 0.7	34.8 ± 0.7	34.9 ± 0.6
Extended study								
Fetlock joint (<i>n</i> = 6)								
Laser	29.9 ± 0.8	29.9 ± 0.8	29.9 ± 0.7	29.9 ± 0.6	30.0 ± 0.6	30.0 ± 0.5	30.0 ± 0.4	30.0 ± 0.4
Control	29.4 ± 0.4	29.4 ± 0.4	29.4 ± 0.4	29.6 ± 0.4	29.7 ± 0.3	29.9 ± 0.3	30.1 ± 0.4	30.6 ± 0.1

*Significantly different from control group ($P < 0.05$).

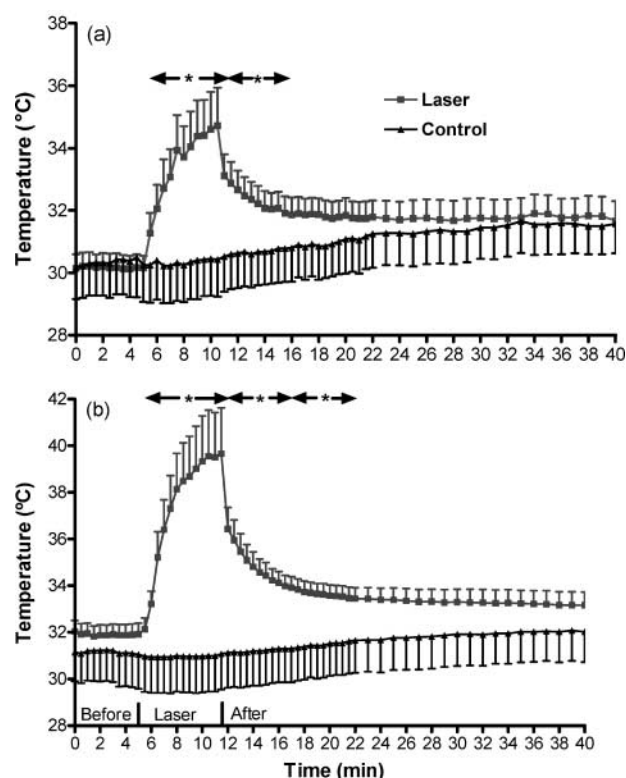


FIG. 3 Temperature in anaesthetized horses during laser treatment: (a) skin, $n = 11$; (b) subcutis, $n = 12$. The treatment was applied to the dorsal projection. Values are expressed as mean $\pm$ SE for the two groups, laser and control. *Significantly different from control group ($P < 0.05$)

An earlier study demonstrated that the guiding light (HeNe source) has no thermal effect²⁸. Consequently, the influence of the guiding light used in this study was disregarded.

It has been reported that the surface temperature of the distal limb in horses differs between individuals^{29–31} and it is known that ambient temperature has an influence on skin temperature^{29,30}. This variation was greater at an ambient temperature of 5°C than at higher temperatures (15–25°C)^{29,31}. In the present study, the temperature varied between approximately 16 and 20°C.

Temperature

The increase in temperature in the skin was acute and of short duration, while the rise in temperature in the subcutis was more prolonged. This could be explained by the different thermal properties of the two tissue types caused by variations in the content of fat, protein and water, as well as tissue density and thermal conductivity¹⁶.

The peak temperatures recorded during the treatment from the dorsal projection are due to the close position to the temperature probes located at the dorsal side of the fetlock joint. This also indicates that the accumulation of energy is local. However,

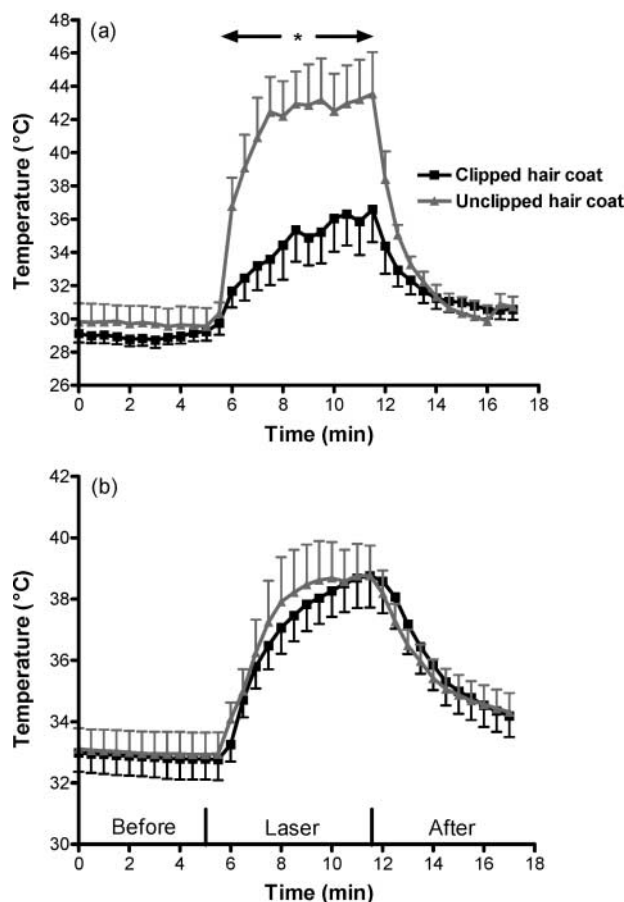


FIG. 4 Temperature in clipped and unclipped, anaesthetized horses during laser treatment: (a) skin, $n = 5$; (b) subcutis, $n = 6$. Values are expressed as mean $\pm$ SE for the two groups, laser and control. *Significantly different from control group ($P < 0.05$)

some accumulation of heat probably occurs since the temperature of the last treatment projection, i.e. the medial projection, was higher than the first, lateral projection.

Despite the differences in the treatment protocol for the standing and anaesthetized groups, a longer accumulation of heat was observed in both skin and subcutis in the anaesthetized group compared with the standing group of horses. However, no statistical difference was seen between the treatment and after-treatment period in the standing group (Table 1)

Table 3 Mean $\pm$ standard error of temperature variables (°C) in clipped and unclipped, anaesthetized horses during laser treatment. The treatment was applied to the dorsal projection only

	Pre-treatment	Treatment	Post-treatment
Skin ($n = 5$)			
Clipped	29.0 $\pm$ 0.4	34.2 $\pm$ 1.6*	31.6 $\pm$ 0.7
Unclipped	29.7 $\pm$ 1.1	41.0 $\pm$ 2.0	32.1 $\pm$ 0.5
Subcutis ($n = 6$)			
Clipped	32.9 $\pm$ 0.6	36.7 $\pm$ 0.7	35.8 $\pm$ 0.8
Unclipped	33.0 $\pm$ 0.7	37.2 $\pm$ 1.0	35.6 $\pm$ 0.5

*Significantly different from unclipped group ($P < 0.05$).

compared with a statistical difference in skin (5 min) and subcutis (10 min) in the anaesthetized group (Table 2). It is likely that the anaesthetized horses were affected, to some extent, by the differences in tissue perfusion due to the position of the limb and the decreased magnitude of blood flow during anaesthesia. It is also known that both halothane and isoflurane induce peripheral vasodilatation and decreased cardiac output. These inhalant anaesthetics override the physiological effects of individual induction agents early during anaesthesia³². Thus, the circulatory effects during anaesthesia may alter the potential for heat dissipation in peripheral tissue.

In the standing group, most standard errors in the pre-treatment periods were greater than in the post-treatment periods. The most likely explanation is that a physiological regulatory mechanism causes an increase in temperature during treatment. It is reported that when tissue temperature reaches a certain level, it triggers physiological responses such as blood flow, and a stabilization of temperature may occur¹⁶. An alternative explanation is a micro trauma caused by insertion of the thermistor. The initial trauma may lead to an increase in temperature due to minor bleeding. The differences in temperature standard error were smaller in the anaesthetized groups, which support these suggestions.

The results of the present study correspond well with those from studies on other modalities with thermal effects. For example, a gel wrap heated to 40°C and applied to the metacarpal region for 30 min raised skin temperature by 5°C. Notably, in most of the treated horses, mild or moderate oedema was seen in the treated leg at the end of the study³³. In another study, therapeutic ultrasound caused a significant difference of less than 1°C between the treated and untreated leg in horses³³ and an increase of approximately 2–5°C in canine thigh muscle³⁴.

Thermal modalities have the strongest influence on superficial tissues but also cause effects on deeper structures, such as muscles, through reflex mechanisms¹⁶. With the protocol used in the present study, warmth receptors and probably also heat-sensitive nociceptors were stimulated. Heat-sensitive nociceptors and warmth receptors may be of importance in the axon-reflex vasodilatation response^{35,36}. Increase in skin blood flow in response to localized heat may initially be mediated by axon reflexes, followed by a second, slower rise primarily dependent on local nitric oxide production^{35,37}. Stimulation of cutaneous C-fibres may also release substances that have a vasodilating and pro-inflammatory effect, and an increase in skin blood flow has been reported in rats following antidromic stimulation of vasoactive nociceptors³⁸. Localized heat has also been suggested as a possible stimulus for activation of the parasympathetic system

through an unidentified co-transmitter released from cholinergic nerves³⁹. Further studies are required to determine whether an increase in blood flow would be achieved with the protocol used in the present study.

For the standing horses, fetlock joint temperature increased over time, but no significant differences were observed between the groups. This increase is most probably caused by the thermistor, especially as the horse was standing and occasionally moved its limb. These findings were confirmed as there was no increase in temperature or significant difference between laser-treated horses and controls when laser was applied to anaesthetized horses after the joint temperature had reached a period of steady state. It is unlikely that the heat accumulated in the subcutis, which acts as a thermal insulator depending on the fat content, had affected the temperature of the fetlock joints.

Literature describing laser treatment focuses mainly on the treatment of human patients. However, available reports do not take into account the effect of the animals' coat of hair on laser treatment. Some authors advise clipping the hair before treatment to optimize absorption of the laser light. In the present study, skin temperature increased by 9.6°C in intact coats, compared with 5.9°C when the coat was clipped. These results correspond with findings from a study on therapeutic ultrasound, which showed a higher increase in surface temperature in dogs with long hair compared with short⁴⁰.

Clinical relevance

In the present study, the laser treatment was well tolerated and, in accordance with earlier studies¹⁶, a moderate to vigorous heating effect was achieved in the skin and subcutis. In designing a rehabilitation programme, it is of importance to select a thermal modality that elevates the temperature to a suitable level at the site of treatment. According to Oostervald and Rasker, it is unsuitable to use modalities that elevate intra-articular temperature when treating active arthritis or secondary synovitis in osteoarthritis²². It is likely that a higher laser dose may result in higher superficial tissue temperatures, but also a possibly unwanted increase of the intra-articular temperature, as well as a higher risk for potential damage to the skin. It is of great importance that the horse is able to perceive pain as a warning that injury threshold levels are exceeded, and that steps should be taken to minimize the effects of repeated exposures. This raises the question of the suitability of sedation of horses during treatment. Since commonly used α_2 -agonists produce both significant sedation and analgesia, use of these drugs may reduce the response to heat and pain. Notably, with the protocol used in this study, there was a minimal risk of thermal injury.

Conclusion

The aim of the present randomized, double-blind study was to investigate if defocused CO₂ laser treatment (71–171 J cm⁻²) affected the temperature of the skin, subcutis and fetlock joint in standing and anaesthetized horses. Treatment with defocused CO₂ laser on the fetlock joint region mediated a significant heating affect in the skin and subcutis, but no differences in fetlock joint temperature were observed. However, it was not shown whether the increase in surface temperature reflects changes in local perfusion, mediates pain relief or restores function. Further research is therefore necessary to describe the physiological and clinical effects of defocused CO₂ laser treatment.

Acknowledgements

The authors are grateful to The Swedish Racing and Totalizator Board (ATG) for financing the study, and to EL.EN. Srl, Italy for supplying the laser system. The authors thank Karin Thulin, Kristina Karlström, Martina Andersson and Anna Edner for technical assistance.

References

- Galetti G (1991). Low-energy density CO₂ laser as deep stimulator: a comparative study. *Journal of Clinical Laser Medicine and Surgery* 9: 179–184.
- Giavelli S, Fava G, Castronuovo G, Spinoglio L and Galanti A (1998). Low level laser therapy in geriatric osteoarticular disorders. *La Radiologia Medica* 95: 303–309.
- Nivbrant B and Friberg S (1992). Laser treatment of knee joint arthrosis seems to be effective but scientific evidence is lacking. *Läkartidningen* 89: 859–861.
- Kaneps AJ, Hultgren BD, Riebold TW and Shires GMH (1984). Laser therapy in the horse: histopathologic response. *American Journal of Veterinary Research* 3: 581–582.
- Lindholm AC, Swensson U, Mitri NDE and Collinder E (2002). Clinical effects of betamethasone and hyaluronan, and of defocalized carbon dioxide laser treatment on traumatic arthritis in the fetlock joints of horses. *Journal of Veterinary Medicine A* 49: 1–6.
- Bhatta N (1994). Comparative study of different laser systems. *Fertility and Sterility* 61: 581–591.
- Thomsen S (1991). Pathological analysis of photothermal and photomechanical effects of laser-tissue interactions. *Photochemistry and Photobiology* 53: 825–835.
- Baker KG, Robertson VJ and Duck FA (2001). A review of therapeutic ultrasound: biophysical effects. *Physical Therapy* 7: 1351–1358.
- Delisa JA (1983). Practical use of therapeutic physical modalities. *American Family Physician* 5: 129–138.
- Kaneps AJ (2002). Thermal response to superficial hot and cold therapy in a horse. In: Millis D and Levine D (eds) *Proceedings: 2nd International Symposium on Rehabilitation and Physical Therapy in Veterinary Medicine*. Knoxville, TN, USA. p. 209.
- Worster AA, Gaughan EM and Hoskinson J (2001). Effects of external thermal manipulation on laminar temperature and perfusion of the equine digit. In: *Proceedings: 47th Annual Convention of the American Association of Equine Practitioners*, pp. 329–333.
- Nannemann D (1991). Thermal modalities: heat and cold. *AAOHN Journal* 39: 70–75.
- Wright A and Sluka KA (2001). Nonpharmacological treatments for musculoskeletal pain. *Clinical Journal of Pain* 17: 33–46.
- Stashak TS (1987). Methods of therapy. In: TS Stashak (ed.), *Adams' Lameness in Horses*, 4th ed. Philadelphia, PA: Lea and Febiger, pp. 840–877.
- Minor MA and Sanford MK (1993). Physical interventions in the management of pain in arthritis. *Arthritis Care and Research* 6: 197–206.
- Lehmann JF (1990). *Therapeutic Heat and Cold*, 4th ed. Baltimore, MD: Williams & Wilkins.
- Draper DO, Sunderland S, Kirkendall DT and Ricard M (1993). A comparison of temperature rise in human calf muscles following applications of underwater and topical gel ultrasound. *Journal of Orthopaedic and Sports Physical Therapy* 17: 247–251.
- Draper DO, Castel JC and Castel D (1995). Rate of temperature increase in human muscle during 1 MHz and 3 MHz continuous ultrasound. *Journal of Orthopaedic and Sports Physical Therapy* 22: 142–150.
- Moritz AR and Henriques FC (1947). Studies on thermal injury. II. The relative importance of time and surface temperature in the causation of cutaneous burns. *American Journal of Pathology* 23: 695–720.
- Weinberger A, Fadilah R, Lev A and Pinkhas J (1989). Intra-articular temperature measurements after superficial heating. *Scandinavian Journal of Rehabilitation Medicine* 21: 55–57.
- Oosterveld FGJ and Rasker JJ (1994). Treating arthritis with locally applied heat or cold. *Seminars in Arthritis and Rheumatism* 24: 82–90.
- Oosterveld FGJ and Rasker JJ (1994). Effects of local heat and cold treatment on surface and articular temperature of arthritic knees. *Arthritis and Rheumatism* 37: 1578–1582.
- Weinberger A, Fadilah R, Lev A, Levi A and Pinkhas J (1988). Deep heat in the treatment of inflammatory joint disease. *Medical Hypotheses* 25: 231–233.
- Sluka KA, Christy MR, Peterson WL, Rudd SL and Troy SM (1999). Reduction of pain-related behaviors with either cold or heat treatment in an animal model of acute arthritis. *Archives of Physical Medicine and Rehabilitation* 80: 313–317.
- Merritt JL, Hunder GG and Reiman HM (1983). Intra-articular temperature: technique and reliability in an animal model. *Archives of Physical Medicine and Rehabilitation* 64: 113–116.
- Edner A, Nyman G and Essén-Gustavsson B (2002). The relationship of muscle perfusion and metabolism with cardiovascular variables before and after detomidine injection during propofol-ketamine anaesthesia in the horse. *Veterinary Anaesthesia and Analgesia* 29: 182–199.
- Edner A, Nyman G and Essén-Gustavsson B. The haemodynamic effects of spontaneous and mechanical ventilation. *Veterinary Anaesthesia and Analgesia* (in press).
- Schindl A, Schindl M, Pernerstorfer-Schön H and Schindl L (2000). Low-intensity laser therapy: a review. *Journal of Investigative Medicine* 48: 312–326.
- Kameya T and Yamaoka S (1968). Effect on atmospheric conditions on skin temperature in horses. *Experimental Reports Equine Health Laboratory* 5: 1–12.
- Webbon PM (1978). Limb skin thermometry in racehorses. *Equine Veterinary Journal* 10: 180–184.
- Palmer S (1983). Effect of ambient temperature upon the surface temperature of the equine limb. *American Journal of Veterinary Research* 44: 1098–1101.

- 32 Taylor PM and Young SS (1993). Does the induction agent affect the course of halothane anaesthesia in horses? *Journal of Veterinary Anaesthesiology* **20**: 84-91.
- 33 Turner TA, Wolfsdorf K and Jourdenais J (1991). Effects of heat, cold, biomagnets, and ultrasound on skin circulation in the horse. In: *Proceedings: 37th Annual Convention of the American Association of Equine Practitioners*, pp. 249-257.
- 34 Levine D and Millis D (2001). Effects of 3.3-MHz ultrasound on caudal thigh muscle temperature in dogs. *Veterinary Surgery* **2**: 170-174.
- 35 Munce TA and Kenney WL (2003). Age-specific modification of local cutaneous vasodilation by capsaicin-sensitive primary afferents. *Journal of Applied Physiology* **95**: 1016-1024.
- 36 Schmelz M, Michael M, Weider C, Schmidt R, Torebjörk HE and Handwerker HO (2000). Which nerve fibers mediate the axon reflex flare in human skin? *Neuroreport* **11**: 645-648.
- 37 Minson CT, Berry LT and Joyner MJ (2001). Nitric oxide and neurally mediated regulation of skin blood flow during local heating. *Journal of Applied Physiology* **91**: 1619-1626.
- 38 Gee MD, Lynn B and Cotsell B (1997). The relationship between cutaneous C fibre type and antidromic vasodilatation in the rabbit and the rat. *Journal of Physiology* **503**: 31-44.
- 39 Kellogg DL Jr, Pergola PE, Piest KL, Kosiba WA, Crandall CG, Grossmann M *et al.* (1995). Cutaneous active vasodilation in humans is mediated by cholinergic nerve cotransmission. *Circulation Research* **77**: 1222-1228.
- 40 Steiss JE and Adams CC (1999). Effect of coat on rate of temperature increase in muscle during ultrasound treatment of dogs. *American Journal of Veterinary Research* **60**: 76-80.