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Pelvic limb thermography in dogs submitted to different thermotherapy modalities

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Abstract: Veterinary physiatry is an area in need of further studies and a discipline in which the protocols used in the veterinary clinical routine are often extrapolated from studies in medicine. This study aimed to evaluate the effectiveness of different types of thermotherapy and massage, through thermography, in promoting heating or cooling in the pelvic limb of healthy dogs. Five healthy adult dogs (male and female) of different breeds were subjected to 5 treatments: G1: massage without oil; G2: oil massage; G3: heating with a thermal bag at 43 ± 1 °C; G4: cryotherapy with ice pack; and G5: therapeutic ultrasound. All animals were submitted to all treatments. Thermographic evaluations were performed with the aid of an infrared camera before the procedure, immediately after treatment, and every minute up to 30 min. Superficial heating ($P < 0.05$) of the pelvic limb was performed with the thermal bag and therapeutic ultrasound modalities, whereas cooling was carried out withan ice bag. Massages with and without oil did not promote heating.Thus, the protocols chosen for the thermotherapy modalities were able to produce a change in surface temperature. Such a change was sufficient to obtain therapeutic effects in dogs, with the exception of massages with and without oil.

Key words: Cryotherapy, heating bag, massage, therapeutic ultrasound

1. Introduction

Thermography is a noninvasive, two-dimensional technique used to measure the surface temperature field of all types of materials [1]. It is a tool capable of showing affects with any type of alteration in blood perfusion [2]. Thermograms allow for the distinction of the heat distribution emitted by the analyzed element, thereby establishing precise temperature measurements and identifying isothermal curves [3].

Thermotherapy consists of applying or removing body heat for therapeutic purposes. It can also be defined as the use of superficial heat and/or cold and deep heat as therapeutic modalities for the treatment of diseases or traumas, and it can be used in veterinary physiotherapy [4,5].

Cold therapy as a method in rehabilitation is called cryotherapy and is related to the reduction of cardinal signs of inflammation (pain, edema, hyperemia, increased temperature, and decreased function) [4]. Heat therapy can be used after the end of the acute inflammatory phase of the healing process, causing dilation of the cutaneous vessels, improving the extensibility of the connective and muscular tissues, and increasing the pain threshold; it is useful before performing exercises and stretches to improve range of motion [6].

A massage is also known to reduce muscle tone and pain, stimulate the flow of the circulatory and lymphatic systems, promote drainage of chemical irritants and metabolism products, and return mobility to adhered or scarred tissues. A massage can relieve spasms of unknown causes that result in the self-perpetuating muscle spasm cycle [7]. Although scientific evidence is necessary to prove the real benefits of massage in companion animals, its potential positive effects in dogs and cats need to be verified[8].

Few publications have assessed the effects of different methods of applying heat, cold, and/or massage in dog rehabilitation, with many protocols being prescribed

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empirically or based on studies carried out on other species of animals or humans. Thus, the present study aimed to evaluate, through thermography, the effectiveness of different types of thermotherapy and massage in promoting heating or cooling in the pelvic limb of healthy dogs. This work may assist in the formulation of protocols aimed at this species.

2. Materials and methods

This study was submitted to the Ethics Committee on the Use of Animals of the Federal University of Acre and approved under protocol 40/2016. Dog owners were contacted, and those who agreed that their dogs participate in the research completed and signed the consent form.

Five healthy adult dogs (2 male and 3 neutered female) of large size were randomly selected; they weighed between 20 and 40 kg, with an age of between 4 to 12 years old. Their body score was determined according to the description of Laflamme [9]. The animals did not show any signs of pain, claudication, asymmetry, or muscle hypotrophy during physical and orthopedical examination.

The animals were sent to the Veterinary Medicine Teaching and Research Unit of Acre's Federal University to perform therapeutic protocols. To reduce factors that could interfere with the temperature of the treated area, the animals were submitted to a session 24 h after performing trichotomy with a stainless steel blade in the middle of the lateral right pelvic limb with a delimited area of 28 cm^2. To carry out the treatments, the dogs were placed in individual kennels in an air-conditioned room at 24 °C for a minimum period of 60 min prior to the session.

The 5 dogs underwent 5 treatments, totalling 25 sessions, with a minimum interval of 24 h for each session. The treatment groups were named as follows: group 1 (G1): heating with hot thermal bag; group 2 (G2): therapeutic ultrasound (US); group 3 (G3): cryotherapy with an ice pack; group 4 (G4): dry massage, and group 5 (G5): massage with oil. For all groups, the session was performed for 10 min and was immediately interrupted in case of vocalization, agitation, or signs of discomfort.

For G1, the thermal bag was heated to 43 ± 1 °C in a water bath, and the temperature was confirmed with the help of an infrared camera. After measuring the temperature, the limb was protected by a thin cotton towel to avoid possible burns.

In the G2 group, the therapeutic ultrasound (Sonopulse III, Ibramed, Amparo, SP) of 3.3 MHz and 1.5 $W/cm^2$was used in continuous mode, with an effective radiation area transducer of 7 cm^2, following the protocol used by Levine et al. [10]. The application was performed with conductive gel with the transducer in circular movements, as recommended by Draper et al. [11].

During the G3 sessions, the ice pack was kept in a freezer at −20 °C and removed at the time of application, in the same way as in G1. In the modalities in which the thermal bag was used, a cut of ethyl vinyl acetate was positioned on the skin around the trichotomized area for thermal insulation of the treated area.

Superficial sliding massage was performed (G4) in the distal to proximal directions, with moderate strength intensity in the lateral thigh region. The same procedure was performed for G5 with the use of massage oil at ambient temperature applied at the beginning of the session and reapplied, as needed, to facilitate sliding during the massage.

Thermographic evaluation was performed with an infrared camera model FLIR Systems AB (FLIR) before the procedure (control), immediately after treatment, and every minute for 30 min. Thereafter, it was coupled to the microcomputer, and the images were analyzed with the aid of computational software FLIR Tools. Statistical analysis was performed using a t-test, with 5% significance.

3. Results

3.1. Hot thermal packs

The thermal bag at 43 °C promoted superficial heating ($P < 0.05$) of the pelvic limb in all dogs immediately after the session (Figure 1). The average temperature of the delimited area of the limb of the animals before the procedure was 35.8 °C; immediately after treatment, the average temperature rose to 40 °C. The temperature increase ranged from 3.6 °C to 5.1 °C among the dogs.

Three animals showed surface temperatures above 40 °C immediately after application of the hot pack. However, in the subsequent minutes, the averages remained below 40 °C. During the evaluations, 80% of the dogs (4/5) exhibited a surface temperature higher than the initial one within 30 min of evaluation. In dog 4 (an elderly 12-year old animal that was overweight with a body score of 9), cooling occurred more quickly, with a return to the initial temperature after 12 min that dropped dramatically during the evaluation.

3.2. Therapeutic ultrasound

There was an increase ($P < 0.05$) in the surface temperature of the pelvic limb area (Figure 2). The results from the examinations on the 5 dogs are illustrated on Figure 3. There was, on average, an increase of 3.76 ± 1.4 °C, where the maximum average observed was 41.1 °C immediately after the end of the treatment. Cooling occurred more quickly than in the treatment with the heating pack, where most of the dogs, except one (dog 2), reached the initial temperature after 2 min.

3.3. Cryotherapy

All dogs presented superficial cooling ($P < 0.05$) of the pelvic limb area submitted to cryotherapy, with an average

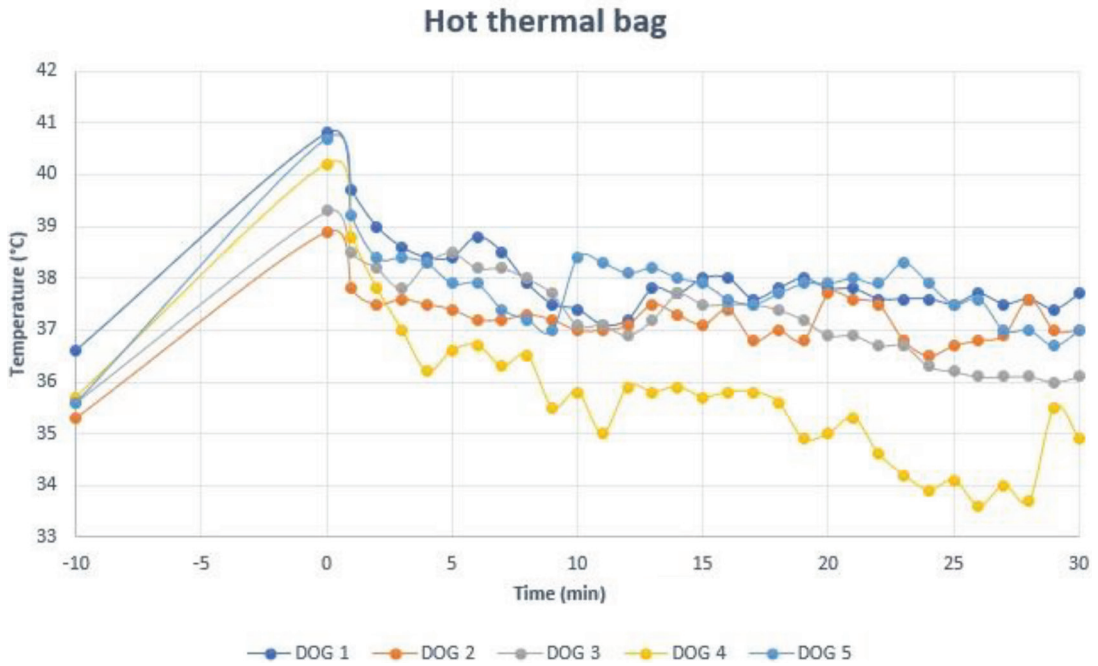

Figure 1. Thermographic analysis of the dogs' superficial pelvic limb temperature before (time: -10 min), immediately after (time 0), and after superficial thermotherapy performed with a thermal pack at a temperature of 43 ± 1 °C.

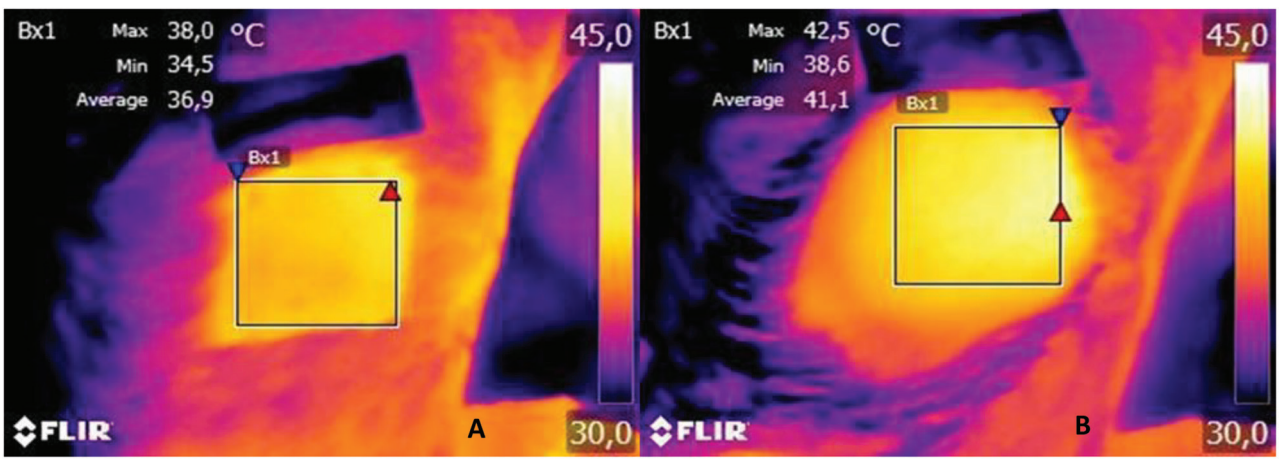

Figure 2. Thermographic image of the right pelvic limb of a dog. A: immediately before the application of therapeutic ultrasound; B: immediately after the application of therapeutic ultrasound.

decrease of 12.4 ± 4 °C, as shown in Figure 4. There were no signs of discomfort, such as agitation or vocalization, or skin burns caused by the cold. Reheating occurred slowly and gradually, and the initial temperature was not reached during the evaluated period, with the exception of 1 dog (dog 2) that returned to the initial value at 10 min after the end of the ice pack application. The same patient showed the least temperature reduction on the treated surface (6.3 °C). Dog 4 showed the greatest cooling and the slowest reheating of the skin during the 30 min of evaluation after treatment. The 3 other patients had similar thermal behavior.

3.4. Massage

Before treatment, the group submitted to massage without oil had an average temperature of 36.1 ± 1.27 °C. Soon after the session, an average temperature of 36.1 ± 0.72 °C was observed. In the dogs that received the oil massage, an average temperature of 35.7 ± 1.21 °C was observed before the session. Immediately after, the average temperature was 36.7 ± 0.62 °C. Therefore, only a massage with oil was able to raise the surface temperature by an average of 1 °C.

Figure 5 summarizes the superficial temperature in the hind limb of dogs submitted to protocols to increase

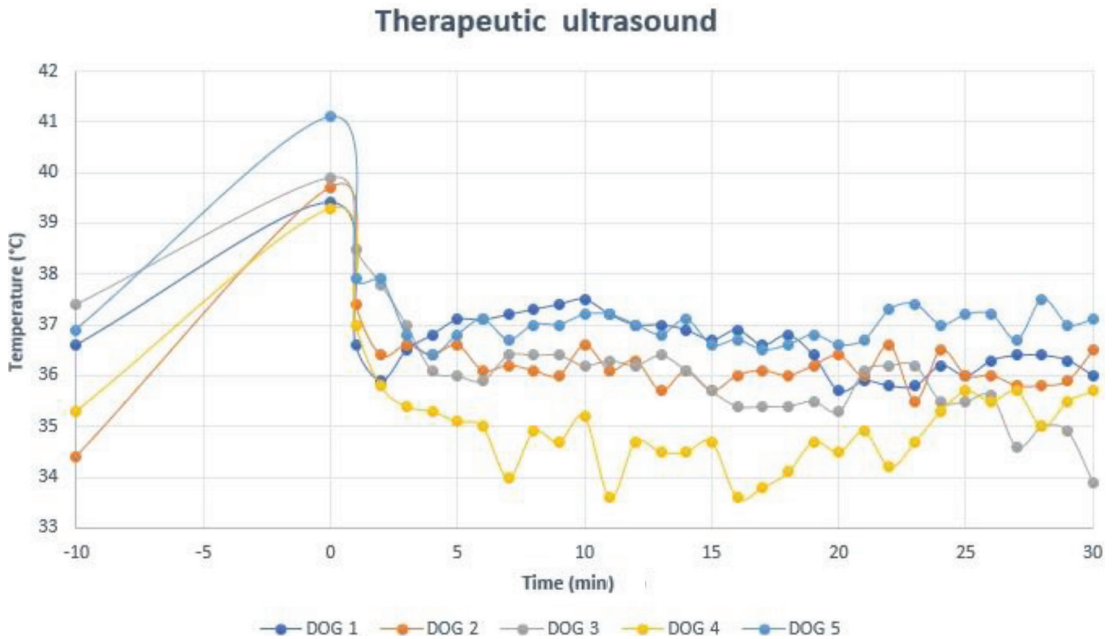

Figure 3. Thermographic analysis of the dogs' superficial pelvic limb temperature before (time: -10 min), immediately after (time 0), and after 3.3 MHz continuous therapeutic ultrasound, with 1.5 W/cm^2 intensity.

heating (heating pack, therapeutic ultrasound, and massage with or without oil).

4. Discussion

The sessions occurred without any complications. The dogs were calm and did not show signs of discomfort when submitted to any of the thermotherapy modalities.

To obtain therapeutic warming, temperature should be kept below 43 °C, with the maximum temperature suggested for applying heat to the skin of healthy dogs at 41 °C [12]. However, Millard et al. [13] used thermal packs heated to 47 °C for 10 and 20 min in healthy dogs with an ideal body score; thermal damage was not observed.

The increase in surface temperature achieved between 3.6 °C and 5.1 °C with thermal pack proved to be efficient to obtain therapeutic benefits, such as increased local oxygenation and metabolism, elevated connective tissue extensibility, and analgesia [12]. Although its effects are restricted to a depth of up to 1.5 cm [13], many adherence conditions are found in this range[11]. The depth of heat penetration can vary between individuals of different species and between different regions of the body; it is also affected by several factors, including depth of subcutaneous tissue, type of coat, and temperature gradient between the heat source and tissue [14].

The impact that heat from superficial thermotherapy modalities has on subcutaneous adipose tissue warrants concern. According to Petrofsky and Laymon [15], heat poorly penetrates through adipose tissue, which may explain the different thermal behavior of dog 4. The authors state that the modalities of superficial physical agents clinically used to warm or cool deep tissues in overweight human patients can be ineffective if applied for short time periods, as the modalities of heat and cold are normally used for 15 min due to the insulating effect of body fat.

In terms of the US treatment, dog 2 did not return to the initial value before 30 min after the end of the application of US and demonstrated a major temperature increase on the treated surface (5.3 °C). This finding was due to the fact that the patient had a well-developed thigh musculature, which may have been the cause for the great heat absorption as tissues with a high protein content heat up much more than adipose or epithelial tissues [16]. This behavior was not observed in the same dog when the animal was treated with the hot pack as the forms of heat transfer differ between the 2 modalities. In surface thermotherapy with a heating bag, the form of energy transmission is by conduction, where direct interaction occurs between the molecules. Conversely, in the use of therapeutic US, conversion occurs, which is the transformation of nonthermal forms of energy (mechanical sound waves) into heat [17]. The temperature rise generated by US depends on multiple factors such as the acoustic and thermal properties of the treated tissue [18,19]. The extent to which a tissue absorbs the energy of an ultrasonic wave varies depending on its type. Tissues with a high protein content, such as muscle and tendon, absorb more energy than those with a low protein content [20,21].

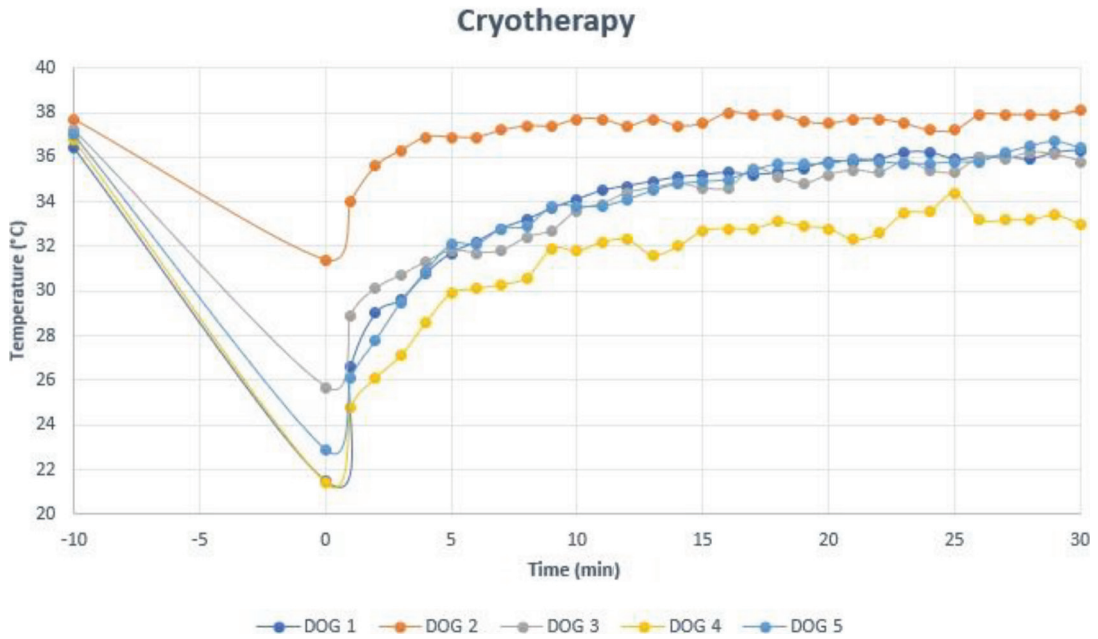

Figure 4. Thermographic analysis of the dogs' superficial pelvic limb temperature before (time: -10 min), immediately after (time 0), and after cryotherapy performed with a thermal pack at a temperature of–20 °C.

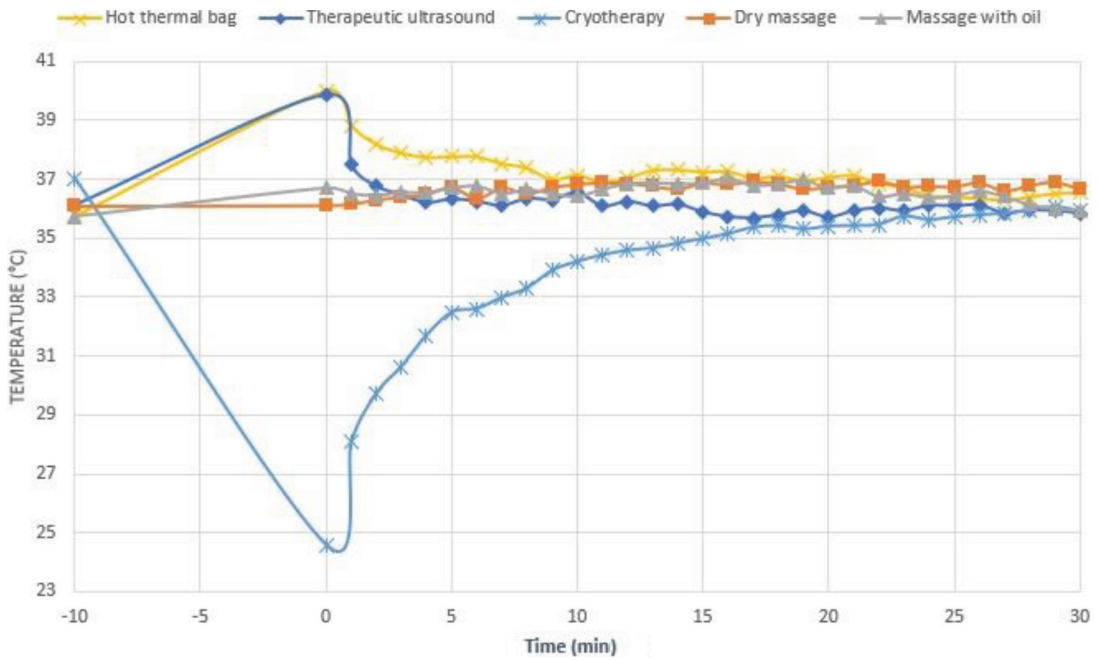

Figure 5. Thermographic evaluation of the dogs' superficial pelvic limb temperature before and after 10 min with a heating pack, therapeutic ultrasound, and massage with or without oil and cryotherapy for 30 min.

Dog 4 showed the lowest temperature increase and the lowest temperatures observed during the 30 min of evaluation after US treatment. One must consider the tissue to be treated and if there is a greater or lesser amount of adipose tissue covering the muscle or areas with bony prominences. The adipose tissue absorbs less ultrasound than the dermis and muscles [10,20], which explains the lowered response, decreased skeletal muscle, and excess of adipose tissue.

The protocol performed in this study proved to be effective in dogs with the same condition. According to Levine et al. [10], after US therapy, tissue temperature

should be raised at least 3–4 °C above normal to obtain maximum increases in tissue extensibility associated with improved flexibility in both humans and animals. The same authors observed that post treatment temperatures remained above the initial temperature for approximately 2 min, corroborating the results of the present study. According to the reviews carried out by Draper and Ricard [11] and Itakura et al. [20], the effects may vary according to the temperature rise delta: heating at 1 °C increases metabolism; from 2 °C to 3 °C decreases pain and muscle spasm, and a change of 4 °C or more increases the extensibility of collagen and reduces joint stiffness.

By contrast, according to Araújo [22], the therapeutic temperature reached in the target tissue is between 40 °C and 45 °C; this range controls the inflammatory reaction and pain in its subacute and chronic stages, thereby increasing tissue healing, reducing edema and ecchymosis, improving range of motion, reducing joint contractures, and promoting drainage.

The cryotherapy protocol showed that the skin's cooling rateis faster than that of reheating. The treatment proved to be effective because vasoconstriction and the inhibition of cartilage-degrading enzymes had already started at 30 °C or below [5]. According to some authors, the normalization of temperature occurs around 15–30 min, which is a considerable time for the therapeutic effect to occur [6,23–25].

Millard et al. [26] did not observe significant changes in the superficial temperature of the epaxial region of dogs when the cryotherapy time was increased from 10 min to 20 min. The same authors suggested that the minimum application time for the ice pack should be 10 min in dogs with ideal body conditions.

According to Akgun et al. [24], the speed of the decrease in muscle temperature depends considerably on the thickness of the fat layer. A direct and clinically important relationship exists between the thickness of adipose tissue and the time required for cooling during cryotherapy, which may explain the response of dog 4 to treatment. The thermal conductivity and diffusivity of adipose tissue are low compared with those of other tissues, such as skeletal muscle.

The time required for the heat to pass through the adipose tissue is longer, making it a more effective insulator compared with the surrounding tissues [27], and it prevented the penetration of the cold into deeper tissues [26]. The fact that dog 2 had exuberant skeletal muscle may have justified less cooling and faster reheating because the high blood flow in the muscle helps dissipate the cold. Therefore, in cases of nonideal body conditions, performing cryotherapy for 20 min may result in stable cooling and rewarming behaviors.

Although Meek [28] reported an increase in skin temperature in hospitalized humans who received a lumbar massage, he observed that this increase did not exceed 1°C. There was no increase in temperature sufficient for the therapeutic effect to occur in both treatments used in this study.

Acute muscle injuries in dogs can be treated routinely with ice packs. For subacute or chronic processes, surface heating must be prescribed [5] and can be obtained with a thermal bag heated to 43 °C and therapeutic ultrasound of 3.3 MHz and 1.5 W/cm². The 10-min period used in the present study was able to cause cooling/heating and can be safely indicated as none of the dogs, regardless of the body score presented, showed pain and discomfort during administration. Despite this, the use of massage, although it has many benefits, should not be performed when the objective is to obtain superficial heating; therefore, it is recommended that other modalities be used for this purpose. Additionally, we observed a need to develop more studies, with individualized protocols in accordance with the patient's body score.

The use of noninvasive techniques for evaluating treatments in animal rehabilitation should be encouraged. Thermography performed with the aid of an infrared camera has been shown to be a simple, easy to access, and effective tool for obtaining surface temperature in dogs.

5. Conclusion

The present study demonstrated that the thermotherapy protocols performed with a hot thermal bag and with the US were effective in producing significant superficial heating of the pelvic limb in dogs, as well as with the cold bag in promoting cooling when administered for 10 min. However, the massage modalities with and without oil were unable to produce superficial heating in the animals studied. A thermographic camera can be used as an effective and noninvasive tool in canine thermotherapy evaluation.

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