CPD article

Superficial heat therapy for dogs and cats, part 1: physiological mechanisms and indications

Superficial heat therapy is an adjunctive pain management tool useful in the management of canine and feline musculoskeletal disorders. Warming tissues improves mobility of musculotendinous units, and there is an additional theoretical basis for the use of heat in enhancing chronic wound healing. Therapeutic benefits of superficial heat therapy result from its effects of enhancing local tissue oxygenation and local tissue metabolism, reducing muscle spasm, increasing connective tissue extensibility and increasing the pain threshold.

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Heat therapy, or thermotherapy, involves warming specific body areas for therapeutic effect. In the first paper of this two-part series, the physiological basis and indications for thermotherapy are outlined. Practical methods of heat application, contraindications and safety considerations will be addressed in the second part of the series.

Heat therapy techniques are classified into superficial and deep heat treatments. **Superficial heat treatments** are those in which heat is applied to the outside of the body. This category includes hot packs, hot wraps and the application of warm water by shower or by partial body immersion. Superficial heat application achieves negligible change in deep tissue temperature, and its effects are therefore restricted to tissues within 1.5 cm of the body surface (Millard et al, 2013). Superficial heating methods are particularly well-suited to use within veterinary practices and as part of a home-care programme by owners, as most necessary equipment is readily available at low cost. However, careful case selection is essential, and correct procedures must be followed to ensure safety and to maximise therapeutic benefit.

Deep heat treatments, such as thermal ultrasound and diathermy, penetrate the body to reach deeper tissue. Requiring specialised equipment and training, and with additional contraindications, the use of deep heat treatments will not be discussed further in this review.

Physiological effects of heat therapy

Superficial heat therapy has the following beneficial effects:

- Enhances local tissue oxygenation
- Increases local tissue metabolism
- Reduces muscle spasm
- Increases connective tissue extensibility
- Increases the pain threshold.

Enhanced local tissue oxygenation

Warming tissue improves local oxygenation in two ways:

Increasing local blood flow. This enhances the supply of oxygen and nutrients and the removal of CO2 and metabolic waste products, benefitting tissue healing and possibly pain management.

The rise in local blood flow obtained with superficial heating techniques has been experimentally demonstrated: hot pack application over the area of the dog gastrocnemius increased muscle temperature by 4.7°C, and increased femoral blood flow (McMeekan and Bell, 1990). Nadler et al (2004) cite further studies by Reid et al (1999) and Erasala et al (2001) demonstrating an increase in deep tissue blood flow with use of a superficial heating pad in human subjects.

Oxygenation via the blood supply is crucial to the processes of fibroplasia and epithelialisation (Aldridge, 2015). By enhancing vascular perfusion, heat therapy is expected to be beneficial during the proliferation and repair stages of wound healing.

However, heat therapy should be avoided over areas of local haemorrhage, oedema and early active inflammation, because these processes would be exacerbated by increased local perfusion.

Shift of haemoglobin-oxygen dissociation curve. As temperatures rise in the range 36-41°C, haemoglobin has a greater tendency to yield its oxygen, due to a right-shift in the haemoglobin-oxygen dissociation curve. Oxygen therefore becomes more readily available to the tissues as tissue temperature increases (Barcroft and King, 1909).

Reduction in muscle tone/spasm

Non-noxious application of superficial heat reduces both resting muscle tone and the amount of muscle spasm during stretch (Lehmann et al, 1974; Lentell et al, 1992), with clinical application in the management of musculoskeletal disorders.

It has been suggested (Heinrichs, 2004; Cameron, 2013) that heat may reduce muscle spasm via its relative effects on nerve firing rates of Golgi tendon organ and muscle spindle afferents. Such changes were demonstrated in a study on moderately-prestretched muscle in anaesthetised cats (Mense, 1978), with a rise in intramuscular temperatures to 42°C resulting in:

- Increased activity in Ia fibres (rapidly responding muscle spindle afferents)
- Increased activity in most Ib fibres (Golgi tendon organ afferents)
- Reduced activity in most group II fibres (slow-response spindle afferents).

The net effect of this is expected to be a decreased firing rate of alpha motor neurons to the extrafusal muscle fibre.

At least in humans, there may be a further psychological component to the reduction of muscle spasm that occurs with heat application, with relaxation not only of local muscle but also of distant striated skeletal musculature being noted (Lehmann et al, 1974).

Increased connective tissue extensibility

Heating soft tissue results in an increase in collagen extensibility, with reduced elastic tension and relatively increased tissue viscosity (Lehmann et al, 1974; Hardy and Woodall, 1998). Superficial heat therapy can therefore be used to improve mobility of healthy and scarred soft tissue structures, including joint capsule, ligament and tendon, as long as they are fairly close to the skin surface.

Hardy and Woodall (1998) discuss the benefits of applying heat to improve the efficacy and safety of therapeutic stretching. They describe the simultaneous use of heat and stretch as having a cumulative effect on collagen structural change, and cite in vitro studies by LaBan (1962) and Rigby (1964) showing that, when heated to 40°C, connective tissue has a significantly greater potential for elongation.

Analgesic effect

In humans, the application of heat can increase the pain threshold (Akin et al, 2001; Michlovitz et al, 2004; Cameron 2013), and clinical experience suggests that this may also be the case at least in some individual cats and dogs.

The analgesic mechanism of superficial heat therapy is uncertain, but may result both from heat-induced vasodilation and from activation of a spinal gating mechanism, with inhibition of nociceptive transmission at the spinal level being initiated by stimulation of cutaneous thermoreceptors (Cameron, 2013). Within ischaemic tissue, accumulation of protons, potassium ions and nociceptive peptides, and reduced oxidation of metabolic products, may contribute to pain (Mense, 1993). Local vasodilation is expected to increase tissue oxygenation and enable dispersal of nociceptive chemicals, thus contributing to analgesia.

Molecular mechanisms involving transient receptor potential (TRP) cation channels are now believed to play a pivotal role in nociceptive transduction and in the development and maintenance of chronic pain. Of at least 28 TRP channels, nine of these, the 'ThermoTRPs', are known to be activated at specific temperatures within the range 10°C and 53°C (Brederson et al, 2013). While research investigates ways to target TRP channels pharmacologically in order to achieve analgesia (Premkumar and Abooj, 2012), heat therapy may well modify nociception via its action on one or more types of TRP channel.

Additionally, experimental alterations in activation of the thalamus and posterior insula have been noted during superficial heating, perhaps suggesting a central nociceptive pathway following skin-warming (Nadler et al, 2004). However, there are as yet no large-scale studies to support this theory.

Muscle spasm (non-postural involuntary contraction of muscle) and unnecessary muscle tension are two potential sources of pain (Simons and Mense, 1998). By reducing muscle tone, heat therapy further improves pain management in animals affected by these conditions.

Increased local tissue metabolism

The rate of enzymatic chemical reactions increases as temperature rises (Miller and Ziskin, 1989) up to a maximum temperature of 45°C. This leads to an increased rate of cellular biochemical reactions, which is beneficial in some situations such as chronic wound healing. During the regenerative and remodelling phases of tissue healing, increased local tissue metabolism hastens the degradation and removal of metabolic by-products of tissue damage (Nadler et al, 2004) and may enhance the controlled apoptosis and re-organization of tissue matrix required for tissue remodelling.

However, heating tissues also enhances the rate of destructive processes by, for example, increasing the activity of collagenases (Harris and McCroskery, 1974). Application of heat to actively-inflamed joints, e.g. with septic or autoimmune erosive arthritis, is therefore contraindicated (Oosterveld and Rasker, 1994).

Indications for superficial heat therapy

Pain management

Management of pain arising from muscle, tendon and myofascia

Evidence for the benefit of heat therapy in management of muscle pain comes from the human field. A Cochrane systemic review of superficial heat therapy for human acute and subacute low back pain found moderate evidence that heat wrap therapy provides a small short-term reduction in pain and disability (French et al, 2006).

Considering more chronic musculoskeletal pain in humans, a significant improvement in wrist pain resulting from 8 hour contin-

uous use of a 40°C air-activated adhesive wrap was demonstrated in a randomized, placebo-controlled trial of 93 people with various painful wrist disorders (strain, sprain, osteoarthritis, tendinosis and carpal tunnel syndrome) (Michlovitz et al, 2004).

For dogs and cats with possible chronic muscle pain, and where there are no contraindications, it is appropriate to add superficial heat therapy to the management programme on a trial basis.

Figure 1. Application of heat pack to reduce unnecessary muscle tension.

Figure 2. A hand-warmer device allows focal application of heat.

Muscular aches in dogs and cats are usually multifactorial, typically involving at least one of the following:

- **Myofascial pain** is a syndrome involving muscle spasm, increased tension and reduced flexibility that has been described in humans (Yap, 2004) and dogs (Janssens, 1991; Frank, 1999). It includes muscle pain from taut bands (groups of muscle fibres that are hard and painful on palpation), trigger points (small and sensitive areas within a muscle that spontaneously or on compression cause pain to a distant region) or tender spots (areas within a muscle that cause local pain). Superficial heat application is described as a treatment option for myofascial pain in humans (Hong et al, 1993) and clinical experience suggests that it may also improve pain management in some dogs.
- **'Unnecessary' muscle tension** (Simons and Mense, 1997) due to:
  - Muscle overload. This may be caused by postural compensation for either conformational abnormality or concurrent injury, especially if the animal continues to pursue repeated high-force activity, or is overweight. Pain is caused by muscle fatigue, sustained muscle contraction with hypoxia and/or the aggravation of trigger points.
  - Psychological distress. Anxiety tends to result in increased muscular activity that is not primarily for motor purposes, thus contributing to pain syndromes.
  - Inefficient use of muscles, e.g. habitual tension in multiple muscle groups during repeated basic functional or athletic activities.

  Used as part of a rehabilitation programme, superficial heat therapy subjectively improves comfort for dogs and cats falling into any of the above three categories of muscle tension. For this purpose, heat may be applied via a heat pack (*Figures 1* and 2) or by warm water showering (*Figure 3*). Management of the underlying cause of muscle tension is of course essential for long-term improvement, e.g. by using behavioural modification techniques, movement retraining and/or tailored exercise prescription.
- **Delayed-onset muscle soreness** involves tenderness and movement-related pain that typically occurs with a delay of approximately one day after exercise (Mizumura, 2009) and which may be more significant in aged animals (Taguchi et al, 2007). Small studies suggest that heat is helpful in reducing the pain of delayed onset muscle soreness (Mayer et al, 2006).

Management of pain associated with degenerative osteoarthritis

Superficial heat therapy is an adjunctive pain management option in cases of degenerative osteoarthritis (Davidson et al, 2005). However, heat is only applicable in the chronic osteoarthritic state, being contraindicated if the joint has become acutely worse and is actively inflamed. During acute flare-ups of osteoarthritis, treatment priorities are exercise modification and medical pain management, NSAIDs being first choice analgesics in the management of osteoarthritic pain (Murrell, 2014).

Warmth applied over a joint and its associated muscles and tendons for 15–30 minutes prior to or during controlled exercise

may improve pain management during activity. The beneficial effect results from enhancement of local blood flow, relaxation of overtight muscles around the joint and increased connective tissue flexibility.

There may also be some rationale for regular application of continuous (i.e. 1–8 hours at a time) low level heat therapy around degenerative joints for improvement in day-to-day pain management (Michlovitz et al, 2004), though this may be difficult to achieve safely in small animals.

Use of superficial heat therapy in other causes of pain

In humans, analgesic effects in renal colic and pelvic pain have been reported (Cameron, 2013), although the mechanism of action is uncertain. A primarily indirect mode of pain reduction, involving reduced superficial muscle spasm, is one possibility. In a randomized, placebo-controlled trial, continuous (approximately 12-hour) low-level heat therapy proved as effective as ibuprofen in the management of period pain (Akin et al, 2001).

The use of superficial heat therapy in the management of visceral pain in dogs and cats has not been investigated. If considering the use of thermotherapy in novel situations, the clinician must bear in mind that contraindications for heat application include acute inflammation.

To help restore mobility of shortened or immobilised musculotendinous units

As previously mentioned, heat improves potential extensibility of connective tissue (Lehmann et al, 1974; Hardy and Woodall, 1998). Thermotherapy is therefore usefully included in the rehabilitation programme in specific clinical situations:

Heat used in combination with therapeutic stretch. Heating soft tissue before a stretch reduces the risk of tissue tearing, and enables less force to be used to achieve the same increased length of the musculotendinous unit (Warren et al, 1976; Hardy and Woodall, 1998). If tissues are pre-heated, a therapeutic stretch achieves better plastic deformation, i.e. the increased length of the musculotendinous unit is maintained to some extent, even after the stretch force is removed (Lehmann et al, 1970; Warren et al, 1976).

A systematic review of the effect of heat applied with stretch in human subjects (Nakano et al, 2012) concluded that superficial heat enhances both the immediate and sustained improvement in range of movement achieved by stretching.

Following orthopaedic surgery. Following fracture repair (Doyle, 2004), cryotherapy is initially appropriate. However, once acute inflammation and oedema have subsided, heat may be used in combination with range of motion and exercise sessions, in order to improve extensibility of connective tissue and therefore reduce risk of post-operative contracture (Davidson et al, 2005)

Following coxofemoral excision arthroplasty, maintenance of coxofemoral range of movement is essential. Heating tense muscle groups immediately prior to rehabilitation exercises may facilitate the range of the pseudo joint by enhancing soft tissue extensibility (Davidson et al, 2005).

Management of post-operative complications. Adaptive shortening of hip flexor muscles may be seen during recovery from pelvic limb orthopaedic surgery, especially if the limb was chronically non weight-bearing pre-operatively. Application of superficial heat over affected muscles by clinician or owner (*Figure 4*) in conjunction with range of movement exercises, soft tissue mobilisation and movement re-education, aims to restore coxofemoral range of movement into extension. If unmanaged, adaptive shortening of hip flexors can lead to chronically reduced weight-bearing.

Figure 3. Warm-water showering is here used to reduce unnecessary tension in Rhomboideus and Trapezius musculature.

Figure 4. Heat application over Tensor fasciae latae and Sartorius musculature to encourage coxofemoral extension. In select cases, owners may be taught how to apply superficial heat therapy as part of their animal's rehabilitation home care programme.

Muscle contracture may be seen post-operatively. In a case of successful management of canine quadriceps contracture, regular heat therapy was used in conjunction with methadone analgesia to relieve muscle spasm and pain and to relax muscles before range of movement and stretching exercises. This rehabilitation programme followed on from surgical quadriceps release and application of a stifle flexion device (Moores and Sutton, 2009).

During tendon healing. During the late (remodelling) stage of tendon healing, heat may be usefully applied in combination with rehabilitation loading and active tissue use, e.g. just prior to therapeutic stretch techniques (Davidson et al, 2005) or before weight-bearing exercises.

Conclusion

In conclusion, superficial heat therapy is a useful modality in both first and second opinion canine and feline medicine, particularly in the management of various musculoskeletal conditions and as an adjunctive pain management tool. CA

KEY POINTS

- Heat enhances oxygenation and metabolic activity of local tissues.
- Superficial heat therapy reduces muscle spasm and increases connective tissue extensibility.
- Superficial heat therapy can increase the pain threshold.
- As adjunctive analgesia, superficial heat therapy is particularly useful in the management of muscular and osteoarthritic pain.
- Heat therapy aids the maintenance or restoration of joint range of movement following orthopaedic surgery or tendon injury.

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