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Superficial Heat and Cold – How to Maximize the Benefits

The wide array of superficial heat and cold modalities offers physicians many options for treating sports-related injuries. Appropriate application of heat and cold therapies can reduce the impact of an injury by relieving pain, reducing swelling, and encouraging rehabilitation.

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Superficial heat and cold techniques are well entrenched in the therapeutic strategies of healthcare professionals who treat sports injuries. These adjunctive therapies, which exert their effects at depths of 1 to 2 cm, are most effectively used in comprehensive rehabilitation in a manner that limits tissue damage, controls symptoms, and returns the injured part to optimal function.

To safely maximize the benefits of these modalities, it is useful to review application principles and to employ a variety of heat or cold therapy options.

What can superficial heat do?

Superficial heat increases tissue temperatures to varying degrees. It has also been shown to increase the extensibility of collagen tissue, reduce muscle spasm, produce analgesia, produce hyperemia, and increase metabolism. (Deep heat is also an important form of thermotherapy.)

Increased tissue temperature depends on the depth and type of the tissue. A "cooling reflex" was initially reported in classic studies by Hollander and Horvath (1) which knee intra-articular temperature dropped with less than 20 minutes of hot pack heating. This principle has since guided treatment recommendations (2). However, recent investigators have failed to reproduce this "cooling reflex" and found that superficial heat rapidly increases intra-articular knee temperature. These investigators (3,4)question the wisdom of heating inflamed joints.

Increased tendon and joint capsule extensibility with superficial heat has been thoroughly studied (5). Prolonged static stretching of a tendon with or immediately after heating can elongate the tendon. Heating at therapeutic temperatures does not significantly lesson tendon strength.

Muscle spasm reduction occurs through direct and indirect reflex effects, predominately the latter (6). Secondary afferents in muscle are responsible for the tonic phenomenon assumed to be involved in secondary muscle spasm. Most secondary afferents slow their firing when heated, which presumably decreases muscle spasm. Additionally, Golgi tendon organs, which inhibit muscle contraction, increase their firing when heated. Heating of skin has also been shown to decrease the activity of gamma fibers (the efferent component of the muscle spindle) through reflex effects.

Analgesia production occurs because heat reduces painful secondary muscles spasm, acts as a counterirritant, and possibly stimulates endorphins. A number of studies (7) have documented that heat increases the pain threshold when applied to a peripheral nerve, to skin, or to free nerve endings. Heat produces pain and tissue damage at tissue temperatures of 113 F (45 C).

Increased blood flow occurs through heat's reflex and direct effects. Heating has a direct effect that relaxes the smooth muscles of vessel walls. Vasodilation may result from a release of inflammatory mediators and from heat's effect on axon reflexes (6). Increased blood flow removes most of the heat applied to skin, leaving little heat to reach deeper tissues. Muscle blood flow is minimally affected by superficial heat. Heat inhibits experimental inflammation (8) but clinical studies are unavailable.

Increased tissue metabolism occurs with the initial rise in temperature, though muscle metabolism decreases with prolonged vigorous heating, perhaps because heat-sensitive enzymes are destroyed. Increased collagenolysis has been found with increased intra-articular temperatures, (9) which has implications for joint integrity. However, Mainardi et al (10) did not find progressive joint destruction with daily heat therapy (electric mitten with maximum temperature of 104 F (40 C)) in patients who had rheumatoid arthritis of the hands.

Effective Heating Strategies

Perhaps the main benefits of heat therapy are to reduce muscles spasm, produce analgesia, and increase flexibility. In many instances, the modalities are therefore used at the post-acute stage after initial pain and edema have subsided. However, heat is often the initial treatment for chronic conditions. Because each patient's needs will vary, it's helpful to keep in mind certain considerations when selecting the appropriate heating technique. Techniques include heat packs, paraffin wax, fluidotherapy, hydrotherapy, and radiant heat. Laser treatment has been used to promote wound healing and to treat arthritis and myofascial pain syndromes, but its use remains controversial. (11)

Determine if the patient's injury needs vigorous or mild heating. Vigorous heating is generally reserved for chronic processes, which are aided by increasing the extensibility of connective tissue, maximally increasing blood flow, or reducing muscle spasm. Vigorous heating is contraindicated for acute inflammation. The therapeutic tissue temperature for vigorous heating is 104 F to 113 F (40 C to 45 C), and the duration of tissue temperature elevation is 3 to 30 minutes.

Mild heating is primarily used to treat acute and sub-acute injuries, though it is contraindicated for certain serious acute injuries such as a sprained ankle. Mild heating can reduce muscle spasm in an acute back injury, help resolve tissue inflammation, and reduce pain. The goal of mild heating is to increase tissue temperature to less than 104 F (40 C). Methods of achieving mild heating include using modalities known to produce mild effects such as dip paraffin, or employing heating modalities at reduced output or for shorter times.

Understand heating patterns

For vigorous heating, the highest temperature needs to reach the site of tissue injury. For example, ultrasound vigorously heats the hip joint but only mildly heats superficial structures such as skin and muscle, whereas superficial heating agents cannot vigorously heat deep joints.

Three main factors affect temperature distribution in tissue: the amount of energy converted to heat at a specific tissue depth, the thermal properties of the tissue, and the modality used and its method of application.

Most superficial heating agents significantly heat skin and subcutaneous tissue, but not deep joints or muscle deeper then 1 to 2 cm. However, superficial heating with a heat mitten (set at 104 F (40 C)) has been found to increase metacarpophalangeal joint temperature from 89.6 to 103.1 F (32 to 39.5 C) (10). In the knee, a joint of intermediate depth, Oosterveld et al (4) found that 10 minutes in a paraffin bath increased intra-articular temperature by 6.3 F (3.5 C)—to 96.8 F (36 C), the temperature needed to increase enzymatic activity (9).

In a study of wet and dry heat, Abramson et al (12) found that patients tolerated dry heating better than wet heating. When compared with dry heat at similar temperatures, wet heat produced significantly higher skin, subcutaneous, and muscle temperatures. However, when dry heat was applied at greater temperatures than were comfortable with wet heat, the same effectiveness as wet heat was demonstrated.

Consider contraindications

Because pain is a critical warning sign of tissue injury, heat therapy is contraindicated at sites of decreased sensation and when the patient's mental status is altered. A bleeding diathesis is a contraindication because heating increases blood flow and vascular permeability. Heating over malignancies is contraindicated because it can accelerate tumor growth and metastasis (6). Heat should not be applied to the gonads or to a fetus.

Tissues with inadequate vascular supply should not be heated because increased metabolic demands can lead to ischemic necrosis. It has been recently shown that in diabetic patients with neuropathy, skin blood flow decreases during local heating in contrast to patients without diabetes and patients with diabetes but no neuropathy. (13) These factors decrease the skin's ability to dissipate heat and probably increase burn risk.

Select the best modality

Choosing the appropriate superficial heating method depends on the shape and area to be treated, the depth of target tissue, whether concurrent exercise is desired, the duration of treatment, as well as more pragmatic factors such as expense and ease of application.

Examining cold benefits

Superficial cold lowers tissue temperature to varying degrees. It also can produce analgesia, reduce edema, decrease muscle spasm, and reduce metabolic activity.

Analgesic effects are mediated by cold's effect on nerves and nerve endings, by its counterirritant effects and by reduction of metabolic activity (6). All nerve fiber types are affected by cold; small myelinated (pain) fibers are affected first, then large myelinated fibers, then unmyelinated fibers. Nerve conduction velocity decreases proportionately to decreasing temperature. Cooling below 68 F (20 C) reduces acetylcholine production. Cold also increases the time of the verve's recovery cycle after excitation and increases the refractory period (6).

The analgesic effect of cold is often used to facilitate activity in an injured limb. However, caution is advised since the analgesia may allow the patient to exceed a desired activity level and cause unwanted tissue damage.

In certain instances, cold treatment may minimize a patient's need for pain medication. Cohn et al (14) randomized 54 patients who had arthroscopic anterior cruciate ligament reconstructions into a placebo group and a group that was treated with a thermal cooling blanket for 4 days. The cold-treated group had quicker transition from injectable to oral medication and less pain medication use. Length of hospital stay was unaffected.

Edema reduction can be achieved with cold under some circumstances. Cold produces vasoconstriction by sympathetic reflex and by its direct effects on the smooth muscle of blood vessels. With a severe drop in temperature (down to 35.6 F (2 C)) or a prolonged but lesser drop in temperature, a cyclical increase in blood flow is seen. This vasodilation is though to be a response to protect tissue.

Sloan et al (15) produced edema in subjects' forearms by injecting inflammatory mediators. Treatment groups included patients receiving cold-water baths, cold and compression via two different methods, and pressure alone. Swelling decreased the most in the groups that received compression and cold.

Hecht et al (16) also demonstrated edema reduction in 36 patients who underwent total knee arthroplasty. The subjects were randomized into a control group and two treatment groups, one administered hot packs and the other cold packs before each exercise session. The cold-treated group had less edema and discomfort, though no differences in range of motion were noted.

Decreased muscle spasm occurs via cold's direct effect on muscle, intrafusal fibers (part of the spindle mechanism), and sensory wrappings of the muscle spindles (6). An important consideration in sports medicine is the effect of cold on strength and endurance. Cooling slows contraction and relaxation. Cooling muscle to less than a temperature of 80.6 F (27 C) reduces and maximal grip strength and maximal sustained contraction. Superficial cold can impair performance in activities that require fine motor control (17).

Muscle spasm in acute back pain can be effectively treated with either superficial heat or cold; relief results from separate mechanisms. Landen (16) used ice massage or hot packs to treat 117 nonrandomized patients who had low-back pain. Hot packs were more effective for treating acute back pain, and ice massage was more effective if pain had been present more than 14 days. Ten minutes of cryotherapy is generally enough to relieve muscle spasm in slender individuals, 30 minutes for obese individuals.

Reduction of metabolic activity from cryotherapy has been documented in a study of intra-articular enzymatic activity (8). Cold can also reduce energy requirements, which may play a significant role in its usefulness in treating acute injuries. Reduced energy requirements may help compensate for vasocongestion, edema, and microvascular injury.

Applying cold therapy

After an acute injury, cold is typically applied with elevation and compression to reduce bleeding, swelling, and pain. It is usually discontinued 2 or 3 days after the injury. Cold modalities include various types of cold packs, crushed ice bags, vapulocoolant sprays, ice water immersion, ice massage, refrigerant inflatable bladders, thermal blankets, and contrast baths. Hocutt et al (19) followed 37 patients who had ankle sprains and presented either on the day of injury or within 2 days of the injury. Patients in the study group were treated with either cryotherapy (ice whirlpool or ice packs) or superficial heat; compression was part of treatment for both. Cryotherapy that began immediately or 1 day post-injury and continued for 3 days resulted in full activity significantly sooner than heat therapy or cryotherapy begun on day 2.

Incorporating cold therapy into a treatment plan requires planning with certain considerations in mind.

Understand cooling patterns
With icing, a drop in skin temperature is almost instantaneous, followed quickly by a drop in subcutaneous temperature. Deeper structures are much less efficiently cooled. The patient initially perceives a sensation of cold, then an ache or burning, and finally cutaneous anesthesia.

In patients who have less than 1 cm of subcutaneous fat, temperature at 1-cm muscle depth drops 3.6-5.4 F (2-3 C) with 10 minutes of ice bag application. However, patients who have more than 2 cm of fat experience little change in muscle temperature even at a muscle depth of 1 cm. The greatest reductions in temperature are achieved with ice water immersion. Intramuscular temperature in the gastrocnemius at a 2.5 cm depth drops by 21.6 F (12 C) when the lower leg is submerged in a 50 F (10 C) water bath for 30 minutes (20).

Joints can be cooled as well. Oosterveld at al found that intra-articular temperatures of the knee dropped from a mean of 89.4 to 72.5 F (31.9 to 22.5C) with 30 minutes of ice chip application. Other joints have not been studied in detail, though joints that are more superficial than the knee should be equally or more efficiently cooled.

Re-warming takes a long time because of vasoconstriction; return to baseline temperature can take more than 1 hour.

Caution required
Prolonged exposure to temperatures below freezing will lead to freezing of tissue. Cold should not be used at temperatures less than 37.4 to 39.2 F (3 to4 C). Pain from cooling is generally felt at tissue temperatures at or below 64.4 F (18 C).

A number of cases of peripheral nerve injury from cryotherapy have been reported. Injury sites have included the peroneal, lateral femoral cutaneous, and supraclavicular nerves. Most patients recover within 4 to 6 months.

Consider contraindications
Severe reactions to cold are rare and are related to hypersensitivity reactions. These include release of histamine (cold urticaria), generalized symptoms from cold hemolysins and agglutinins, and a generalized reaction from cryoglobulins. Cold is contraindicated for patients who have developed hypertension during cold treatment or have a cold allergy (hives, joint pain) or cryoglobulinemia. Ice water immersion carries the most risk of severe reaction.

Cold should not be applied to areas of reduced skin sensitivity, or in patients who have Raynaud's syndrome or sickle cell anemia. In people who peripheral vascular disease, cold can further impair local blood flow.

Select the best modality
As with heat modalities, cold modalities vary in effectiveness, ease of exercise during application, and expense McMaster et al (22) evaluated a number of cold therapies to assess their relative effectiveness. They found that ice chips in a plastic bag were the most effective local application method, followed by use of frozen gel packs, endothermic chemical reaction packs, and, finally, inflatable plastic envelopes injected with a gas refrigerant. Frozen gel packs and blue ice packs were significantly more effective than the latter two modalities.

Ice in the form of crushed ice bags, ice massage, or ice water immersion should be applied for 15 to 20 minutes at a time and can be applied several times a day. Prolonged ice application beyond 1 to 2 days has been shown to impair healing (23), carry a risk of nerve injury and frostbite, and increase edema. Bugaj (24) found drops in skin temperatures down to 42.8 F (6 C) with 10 minutes of ice massage and found analgesia at a skin temperature of about 57.2 F (14 C). He found termination of analgesia at about 60.8 F (16 C). The mean analgesic effect lasted about 3 minutes after treatment. Frostbite is not considered a risk from 10 minutes of ice massage-the typical treatment time.

Frozen gel packs are convenient and reusable. One-use endothermic reaction cold packs are convenient, but they don't get as cold as reusable ice packs do and they are expensive. Reusable ice packs require an insulating towel between the pack and the skin to avoid nerve injury and frostbite.

Vapulocoolant sprays can drop skin temperatures precipitously- to 45 F (7.2 C)-when spray is applied intermittently for 15 to 30 minutes. (25) Muscle 1.25 inches deep and intra-articular knee temperatures showed drops in temperature of about 9 F (5 C). They are most often used in spray and stretch techniques. Vapulocoolant sprays, however, have come under fire because they contain chlorofluorocarbons that can harm the ozone layer (26).

Refrigerant inflatable bladders combine cold and compression, which in clinical studies has been more effective than cryotherapy alone, though the cryotherapy value of the bladders is considered minimal (19).

Thermal cooling blankets are improving postoperative treatment for some patients. Patients receiving treatment with cooling blankets have had better outcomes regarding effusion, walking, narcotic use, range of motion, quadriceps function, and pain.

Contrast baths are frequently used, despite the limited research on their effectiveness. Techniques vary, including beginning and ending treatment with cold and vice versa. A frequently cited, though unsubstantiated, rationale for using contrast baths is that alternating vasoconstriction and vasodilation produces a pumping or massage effect that reduces intercellular fluid.

Implement a practical plan

The cost, sophistication, and availability of superficial heat and cold modalities varies, and physicians often have to balance these factors with the demands of the patient's sport. However, inexpensive techniques can achieve excellent results-even in casual exercisers who will be heating or icing their injuries at home.

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