Ice Therapy: How Good is the Evidence?

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Ice, compression and elevation are the basic principles of acute soft tissue injury. Few clinicians, however, can give specific evidence based guidance on the appropriate duration of each individual treatment session, the frequency of application, or the length of the treatment program. The purpose of this systematic review is to identify the original literature on cryotherapy in acute soft tissue injury and produce evidence based guidance on treatment. A systematic literature search was performed using Medline, Embase, SportDiscus and the database of the National Sports Medicine Institute (UK) using the key words ice, injury, sport, exercise. Temperature change within the muscle depends on the method of application, duration of application, initial temperature, and depth of subcutaneous fat. The evidence from this systematic review suggests that melting iced water applied through a wet towel for repeated periods of 10 minutes is most effective. The target temperature is reduction of 10 – 15 °C. Using repeated, rather than continuous, ice applications helps sustain reduced muscle temperature without compromising the skin and allows the superficial skin temperature to return to normal while deeper muscle temperature remains low. Reflex activity and motor function are impaired following ice treatment so patients may be more susceptible to injury for up to 30 minutes following treatment. It is concluded that ice is effective, but should be applied in repeated application of 10 minutes to be most effective, avoid side effects, and prevent possible further injury.

Key words: Cryotherapy - soft tissue injury - systematic review.

Introduction

Ice is commonly used in clinical practice. Hippocrates, according to Rivenburgh [53], was the first physician to use cold in soft tissue injury by applying ice and snow. In the 1940's [6], cold was recommended only in the first 30 – 60 minutes but, by the 1950s, it was used up to 24 – 72 [5] hours after injury. Early research [17,19] examined the effect of ice in injured army recruits, and found that those treated with ice after injury returned to duty earlier. Ice therapy is now established as a key component of soft tissue injury treatment but there is little consistency in the advice [30,31] and other modalities appear to have had some success in the injury treatment. That different forms of treatment appear to be effective may be due either to a non specific anti-inflammatory effect or simply that soft tissue injury improves with time. There are theoretical reasons, however, why both heat and cold may be effective [29]. Heat causes vasodilation, an increase in oxygen supply and increase in metabolism. The increased blood flow to an injured area may help remove cellular debris, increase nutrient delivery, and hence tissue repair. Heat may also increase the pain threshold, relieve muscle spasm and decrease muscle spindle activity and sensitivity to stretch. These effects could potentially improve healing through an increase in tissue antibodies, cellular activity and supply of tissue nutrients. Cooling is very different yet both modalities appear to have an anti-inflammatory effect.

The aim of this systematic review is to identify the original literature on cryotherapy in acute soft tissue injury and produce evidence based guidance on treatment. The specific objectives are to determine the effectiveness of ice in reducing tissue temperature using different methods of ice application, at differing temperature and duration, and to determine the depth of the cooling effect. This review also sought to identify clinical hazards in ice therapy, and to make recommendations based on the evidence.

Method

A literature search was performed using Medline, Embase, SportDiscus and the database of the National Sports Medicine Institute (UK) using the key words ice, injury, sport, exercise. Studies were included if they described original research examining the effect of cold application. This strategy identified 148 references after excluding unrelated articles. We also

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searched the reference lists of review articles (n = 12) and a number of major textbooks held personally and those held by the library of the British Medical Association, the National Sports Medicine Institute in London and at the University of Wisconsin (n = 39). Only those studies which described original research relating to cryotherapy in soft tissue injury are included in this review.

Skin temperature

Measuring the effect of ice on skin temperature is relatively uncomplicated. Ebrall's group [14], using skin telethermography, found that 5 minutes of cooling using a wet pack reduced skin temperature to 7.6 °C, and that, after 10 minutes of cooling, the skin temperature was 5 °C. Using a repeat protocol of 10 minutes of ice followed by 10 minutes recovery [15], skin temperature was reduced to less than 20 °C for 63 minutes and to under 15 °C for 33 minutes. Comparing wet ice, dry ice and cryogen packs, the mean skin temperatures recorded after 15 minutes were 12 °C, 9.9 °C and 7.3 °C respectively with no change in temperature at 1 cm proximal or distal to any of the cooling agents. Holcomb and colleagues [23] found skin temperatures using the standard ice pack (1 kg ice in a plastic bag) of 19 °C initially with a more gradual drop to 14 °C at 30 minutes. Palmer and Knight [49] found an attenuation of the ice effect when applied following 15 minutes exercise but, of course, temperature changes within the muscle are of much more clinical importance [24].

Depth of temperature reduction

There is evidence that the optimum temperature range for reduction of cell metabolism, without causing cell damage, is in the range of 10 – 15 °C [53] but there also may be a distinction between the use of ice in first aid treatment and in rehabilitation [3].

Animal studies

Lievens and Leduc [37] examined the effect of cold applied to the skin of the mouse and found that temperature lower than 15 °C produced an increase in blood vessel permeability with fluid extravasation and oedema. In a study of the effect of cryotherapy on the deep quadriceps muscle of dogs [41], ice packs were the most effective when compared with gel packs and chemical cold packs. A study of ice application for 20 minutes in sheep [56] found that intramuscular temperature reduction did not return to pretreatment levels after 2 hours and when ice was applied a second time, intramuscular temperature continued to fall. Interestingly, higher temperatures were recorded in the traumatised limb.

This effect of ice after injury has clinical importance. Ice significantly reduced oedema in rabbit forelimbs subjected to a crushing injury with cooling to 30 °C more effective than cooling to 20 °C [42]. In contrast [40], rabbit limbs cooled after fracture developed more swelling than those maintained at normal temperatures. Histological studies show [16], however, that although there was increased soft tissue swelling, the inflammatory reaction was reduced. There is a difference in the effect of ice application on muscle micro circulation. In a study of the effect of ice on injured rat muscle, cryotherapy did not reduce microvascular diameters or decrease microvascular perfusion [11]. The duration of treatments in these animal studies was longer than those usually used in clinical practice and we cannot necessarily extrapolate these effects to humans. Animal studies, in general, suggest a target optimal temperature of 10 – 15 °C.

Human studies

Human studies are much more clinically relevant but comparison between studies is difficult as investigators often use different protocols and measure temperature at various depths (Tables **1 – 3**). Hobbs [21] applied ice continuously for 85 minutes and found a final temperature reduction at 7 cm, 6 cm and 4 cm of 5 °C, 9 °C, and 7 °C. Hartvicksen [18], using an ice towel application, noted a temperature reduction from 35 °C to 28 °C over 40 minutes, where it remained for up to 30 minutes after removal of the ice pack. Ice massage is often used as an alternative to direct ice application [38,57] and may, indeed, cool muscle more rapidly [58]. Myrer and colleagues [47] found that muscle temperature decreased by 7 °C over a 20 minute treatment period. Merrick's group [45] found the temperature reduction at 1 cm below the fat layer and at 2 cm below the fat layer to be greater with compression at 12.8 °C and 10.1 °C. Compression increases contact between ice and skin which may improve conductivity and, secondly, compression may reduce blood flow and limit rewarming so that ice with compression appears to be more effective in reducing temperature than ice application alone.

Two further studies help our understanding of the effect of ice at muscle level. Draper and colleagues [12] measured the effect of 10 minutes of ultrasound alone versus ultrasound preceded by icing on the intramuscular temperature at a depth of 5 cm of the Triceps. Ultrasound alone raised the temperature by 4 °C (+/-0.83) whereas ultrasound preceded by 5 minutes precooling increased the temperature by only 1.8 °C (+/-1.0). In a similar study by the same group [52], 10 minutes of ultrasound increased intramuscular temperature at 3 cm depth in the gastrocnemius by 2 °C in contrast to ultrasound preceded by 15 minutes of precooling with ice where the temperature did not increase, even to baseline.

Hocutt et al. [22] highlighted the insulating effect of subcutaneous fat and suggested that significant cooling occurred with ice application of 10 minutes to a depth of 2 cm in those with less than 1 cm of fat. They suggested that, in athletes with more than 2 cm of fat, cooling was required for 20 – 30 minutes. Myrer and colleagues [46] also found that the depth of adipose tissue was a significant factor in the first 15 minutes of ice therapy showing an inverse relationship between adipose tissue and temperature decrease. Mc Master [43] reminds us of the low thermal conductivity of subcutaneous fat tissue and points out that applications for short periods may be ineffective in cooling deeper tissues. The effect of adipose tissue in insulation has been mentioned by other authors [26,36] and clearly this should be taken into consideration in cold therapy.

In summary, various studies have used ice application for periods from 5 minutes to 85 minutes. There is evidence of a reduction in temperature in the first 10 minutes with little further reduction from 10 to 20 minutes. The temperature reduction is also related to the area of contact between the surfaces, the temperature differential and the tissue conductivity. Most

Table 1 Application of ice for 5 minutes

Author	Depth cm	Mode of application	Site	Temperature drop degrees °Celsius	Method of measurement
Myrer et al. 1997	Subcut	1.8 kg ice pack approximately 25x30x5 cm (n = 16)	Triceps surae	10.9 +/- 2.23 (2SE)	Physitemp MT-26/2 and MT-26/4 Physitem Instruments, Inc, Clifton, NJ
Waylonis 1967	Subcut	Ice massage using ice cubes in 8 oz paper cups to an area 4x6 inches for a period of 5 mins (n = 12)	Posterior thigh Calf	13.5 12.3	Tele-thermometer Yellow Springs instrument Company, Ohio
Waylonis 1967	1 cm	Ice massage using ice cubes in 8 oz paper cups to an area 4x6 inches for a period of 5 mins	Posterior thigh Calf	8.8 6.2	
Myrer et al. 1997	1 cm	1.8 kg ice pack approximately 25x30x5cm	Triceps surae	1.94 +/-2SE (1.43)	
Waylonis 1967	2 cm	Ice massage using ice cubes in 8 oz paper cups to an area 4x6 inches	Posterior thigh Calf	4.1 1.1	
Lowden and Moore 1977	2 cm	Ice massage to the entire length of the biceps of the non dominant arm	Biceps brachii (n = 12 students)	17.9	
Rimington et al. 1994	3 cm	Ice bags (1L of ice in 8 inch x 12 inch plastic bags)	Medical aspect gastrocnemius (n = 16)	0.8 approx	Thermister. Phystemp Instruments, Clifton, NJ
Waylonis 1967	3 cm	Ice massage using ice cubes in 8 oz paper cups to an area 4x6 inches	Posterior thigh Calf	1.1 0.2	Tele-thermometer Yellow Springs instrument Company, Ohio
Waylonis 1967	4 cm	Ice massage using ice cubes in 8 oz paper cups to an area 4x6 inches	Posterior thigh Calf	0.4 00	23 gauge thermister needle (Phystek MT – 23/5, Physitemp Instruments, Clifton, NJK)
Draper et al. 1995	5 cm	Ice bag filled with 1L of crushed ice (n = 16)	Medical aspect Triceps surae	0.5+/-0.21	

published studies are not controlled for the area of ice application, the mode of application, depth of subcutaneous fat, method of calculating depth, or method of measuring temperature. Cooling is reversed by natural tissue rewarming, so that any increase in blood flow will raise tissue temperature. In the studies cited, there is wide variation in the temperature recorded with large standard deviations in both animal and human and, in animal studies, the temperatures in different limbs in the same animal were rarely identical.

Contrast therapy

Myrer [47] measured subcutaneous temperature 1 cm below the subcutaneous fat when comparing the effect of a 20 minute ice pack application with contrast therapy (5 minutes of heat with a hydrocollator pack followed by 5 minutes of cold with an ice pack, repeated twice). Intramuscular temperature did not fluctuate over the 20 minute period with contrast therapy, although there was a significant temperature decrease with ice alone.

Application of different modalities

Cold can be applied in different ways. It may be applied directly, using proprietary ice packs, convenience frozen packs (e.g., frozen peas), ice massage using ice in paper cups, frozen gel packs, chemical packs and topical coolants. The standard ice application of melting iced water ensures a constant temperature of 0 °C. Ice taken straight from a freezer may be below freezing point, and reusable gel packs may be as cold as –5 to –15 °C. If applied directly to the skin, these may cause tissue damage and frostbite. Deep penetration of cold is necessary to have any effect on muscle tissue thus topical sprays can have little effect.

Barrier effect

Ice is rarely applied directly to the skin, due to the risk of ice burns [32]. Using a barrier between ice and the skin may however reduce the effect of ice application. LaVelle and Snyder [34] compared the effect of commonly used protective barriers and found that, after 30 minutes ice application, the mean temperature was 30.5 °C using a padded bandage, 20.5 °C with a bandage alone, 17.8 °C with a dry washcloth and 10.8 °C with no barrier and 9.9 °C with a damp washcloth. This has important clinical implications. There was little difference when ice was applied using a damp cloth barrier, compared with chipped ice in a plastic bag applied directly. Cold was not however conducted though a padded elastic bandage.

Effect on blood flow

Blood flow studies are variable and, although there is usually vasoconstriction in the skin following ice application, there may be an increase in skin blood flow immediately following local ice application. Known as the 'hunting reflex', this is a

Table 2 Application of ice for 10 minutes

Author	Depth cm	Mode of application	Site	Temperature drop degrees °Celsius	Method of measurement
Waylonis 1967	Subcut	Ice massage unsing ice cubes in 8 oz paper cups to an area 4x6 inches (n = 12)	Posterior thigh Calf	11.7 Thigh 12.3 Calf	
Myrer et al. 1997	Subcut	1.8 kg ice pack approximately 25x30x5cm	Triceps surae	13.8	
Waylonis 1967	1 cm			11 Thigh 6.2 Calf	
Myrer et al. 1997	1 cm below fat			3.9	
Waylonis 1967	2 cm			5.2 Thigh 1.1 Calf	
Rimington et al. 1994	3 cm	Ice bags. 1L of ice in 8 inch x 12 inche plastic bags (n = 12)	Medical aspect gastrocnemius	1.2	
Waylonis 1967	3 cm			1.4 Thigh 0.2 Calf	
Waylonis 1967	4 cm			0.1 Thigh 0.0 Calf	

Table 3 Application of ice for 20 minutes

Author	Depth cm	Mode of application	Site	Temperature drop degrees °Celsius	Method of measurement
Myrer JW et al. 1997	Subcut	1.8 kg ice pack approximately 25x30x5cm	Triceps surae	17.0	
Myrer JW et al. 1997	1 cm below subcut fat and skin			7.1	
Hartviksen et al. 1962	3	Ice granules adhering to a towel	Gastrocnemius	7	Needle electrode
Hobbs KT 1983	4	Ice application not specified	Thigh	1.1	Thermometer
Hobbs KT 1983	6			1.0	
Hobbs KT 1983	7			1.5	

physiological reflex action to protect tissue from ice damage [8]. Kellet [27] discussed this in his review quoting Pappenheimer [50] and Barcroft [2]. The theoretical basis for this effect is that ice causes vasoconstriction, which helps reduce haemorrhage, but when temperature reduction is so low that it may compromise tissue viability, there is a reflex vasodilation. Hence, vasoconstriction and vasodilation may alternate in a 15–30 minute cycle.

Knight and Londeree [29] compared blood flow to the ankle under six experimental conditions and concluded that there was no cold induced vasodilation resulting from the application of cold pack in this study. Similarly, Baker and Bell [1] found no significant decrease in blood flow with either application of an ice pack or ice massage. Ho and his colleagues [20] performed one of the most interesting studies, using triple phase technetium bone scans, and concluded that the temperature response in a joint is related to the temperature of the ice, the length of time of cooling, the patient's body temperature and skin temperature.

Muscle strength

Cooling muscle reduces strength of planter flexion [48], and can impair functional performance tests in uninjured football players [10]. In contrast, cryotherapy had no significant effect on peak torque but it did increase muscle endurance [28]. Meeusen and Lievens [44] suggest that motor performance is impaired with a critical temperature of 18 ºC.

Nerve conduction

Local cooling slows nerve conduction. Lee and her colleagues [35] demonstrated that ice application reduced nerve conduction velocity, slowing of the stretch reflex, and that the effect was greatest with superficial nerves. Ice had a relatively long lasting effect and nerve conduction velocity had not returned to normal for 30 minutes after ice therapy for 24 minutes. Cold can also reduce muscle spasticity, perhaps through its influence on skin receptors and later on the muscle spindle [18].

Peripheral nerve damage may be among the side effects of prolonged ice therapy [9,13,39]. Ice is often used to produce analgesia, which is consistent with its neurological effects [7]. Cold blocks sensory fibres sooner than motor fibres and neurological impairment which affects position sense could also have important clinical implications. One study [33], however, found no statistically significant difference in eight repositioning trials and concluded that ankle joint position receptors are resilient to this form of ice treatment.

Clinical application

One of the few clinical evaluations [25] of ice application, a retrospective observational study in a sports injury clinic, found that those treated with ice had shorter treatment and fewer appointments. Basur [4] showed that the period of disability following ankle sprain was reduced from 15 to 10 days and Hocutt and colleagues [22] demonstrated recovery in grade 3 ankle sprain in 6 days following early cryotherapy compared to 11 days for late cryotherapy and 15 days for heat. In grade 4 ankle sprain, the time to recovery after early cryotherapy was 13 days compared to 30 days for late cryotherapy and 33 days for heat. Cryotherapy begun on day one was more effective than cryotherapy begun on day 2.

In a clinical trial of cold compression combination therapy [55] (Cryocuff™; Aircast Inc., Summit, New Jersey, USA) there was symptomatic relief in 131 patients with knee pain. Similarly, rapid pulsed pneumatic compression, together with cold, was found to be an effective method of controlling pain, loss of motion and oedema in acute lateral ankle ligament sprain [51]. Neither of these studies had control groups.

Conclusion

Temperature changes within a muscle depend on the method of application, the duration of application, initial temperature and the depth of subcutaneous fat. Temperature continues to drop after ice application. The optimal method of ice application is wet ice applied directly to the skin through a wet towel and the target temperature reduction is to 10–15 °C. There is no evidence from the literature suggesting an optimal frequency or duration of treatment but the consensus appears to be that repeated applications of 10 minutes are effective. We have little evidence on the effect of subcutaneous fat and few recommendations take this into consideration. Exercise influences blood flow and intramuscular temperature changes but most studies have been undertaken in resting uninjured athletes and one cannot necessarily extrapolate these findings to athletes who are active or who have had a significant injury. Contrast therapy appears ineffective in reducing intramuscular temperature and topical sprays, while lowering skin temperature, have little effect on muscle temperature.

Cryotherapy can reduce pain. But, there is impairment of reflex activity and motor function after ice treatment and players may be more susceptible to injury for up to 30 minutes following treatment. Ice may also impair proprioception. Ice should not be applied for long periods over superficial nerves due to the risk of nerve damage. Ice applied directly to the skin may produce ice burns but using a protective barrier can reduce the potential for such burns. A damp cloth barrier is ideal while cold is not conducted through padded elastic bandages. Repeated applications of ice appear to help sustain the reduced muscle temperature without compromising the skin, and skin and superficial temperature can return to normal while deeper muscle temperature remains low.

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