Treating Arthritis With Locally Applied Heat or Cold

Fredrikus G.J. Oosterveld and Johannes J. Rasker

The scientific basis for the treatment of arthritis with locally applied heat or cold is reviewed. Experimental studies in vitro, in animals, in healthy subjects, and in patients are considered. Results of investigations of the effects of locally applied heat or cold on the deeper tissues of joints and on joint temperature in patients are not consistent. In general, locally applied heat increases and locally applied cold decreases the temperature of the skin, superficial and deeper tissues, and joint cavity. Most studies dealing with the effects of heat and cold on pain, joint stiffness, grip strength, and joint function in inflamed joints report beneficial effects. In vitro studies show that higher temperatures increase the breakdown of articular cartilage and tissues that contain collagen. Therefore, one goal of physical therapy should be to decrease intraarticular temperature in actively inflamed arthritic joints.

INDEX WORDS: Physiotherapy; thermotherapy; arthritis; osteoarthritis; heat; cold.

THE THERAPEUTIC VALUE of heat and cold in rheumatic complaints was well known in ancient Greece and Rome. Both can relieve pain and diminish inflammatory symptoms, but the exact indications for thermotherapy remain unclear. The basis for its application in rheumatology is largely empirical. Therefore, we have reviewed the English, French, German, and Dutch literature.

IN VITRO STUDIES

In rheumatoid arthritis (RA) and active osteoarthritis (OA), destructive enzymes are produced in the inflamed joints.[1-6] The activity of these cartilage-degrading enzymes, particularly collagenase, elastase, hyaluronidase, and protease, is influenced by local joint temperature. At temperatures of 30°C and below, the activity of destructive enzymes is negligible.[3-5,7]

Harris et al studied the influence of temperature on the activity of human rheumatoid synovial collagenase.[7] They found that the destruction of cartilage by collagenase increased with increasing temperature. At temperatures found in knee joints affected by RA (±36°C), collagenolyses is four times greater than at temperatures normally found in healthy knee joints (±33°C).[7] The synthesis rates of hyaluronic acid in cultures of normal and rheumatoid human synovial cells increase as local temperature increases from 32°C to 39°C and decrease sharply at 41°C.[8] In rabbit articular cartilage, temperatures above 38°C diminish metachromasia, reduce the rate of proteoglycan synthesis, and increase degradation of the macromolecules of the cartilage matrix.[9]

Ligaments in canine knee joints become increasingly lax as ambient temperature increases from 2°C to 37°C and undergo irreversible damage at 42°C.[10]

ANIMAL STUDIES

In animal experiments, intraarticular temperature increases with application of superficial heat, microwave diathermy, short-wave diathermy, and ultrasound treatment.[11-13] The superficial application of cold reduces intraarticular temperature.[11,12,14] Temperatures in various tissues have been decreased by several cold stimuli[12,15] and increased by treatment with

From the Department of Rheumatology, Hospital Medisch Spectrum Twente, and the University Twente, Enschede, the Netherlands.

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Fredrikus G.J. Oosterveld, RPT: *Physiotherapist;* Johannes J. Rasker, MD, PhD: *Consultant Rheumatologist and Professor, University Twente.*

Address reprint requests to Fredrikus G.J. Oosterveld, RPT, Department of Rheumatology, Hospital Medisch Spectrum Twente, Postbus 50000, 7500 KA Enschede, the Netherlands.

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heat.[12,13] Animal joint findings are summarized in Table 1.

In acute urate-induced synovitis in dogs, ice packs reduce joint temperature by 1.7°C and significantly ($P < .05$) lower the number of granulocytes. Hot packs (60°C) increase intraarticular temperature by 0.6°C and increase the number of granulocytes ($P < .05$, treated *v* control). Synovial fluid volume and polymorphonuclear infiltration of urate-induced synovitis are decreased by cold and increased by heat. In chronic urate-induced synovitis in dogs, no significant changes are found after treatment with either heat or cold[11] (Table 1).

In a histological study using 10 pigs, experimentally induced sprains of the radiocarpal ligament were treated by applying crushed-ice packs for 20 minutes, allowing 1 hour of rest, and then applying crushed-ice packs for another 20 minutes.[16] This treatment increased swelling in the subcutaneous tissue but reduced posttraumatic inflammation as measured by counts of polymorphonuclear leukocytes, plasma cells, and lymphocytes and by the amount of fibrous exudate.

STUDIES IN HEALTHY HUMAN SUBJECTS

Few studies have dealt with intraarticular temperatures and changes induced by physiotherapy in healthy human subjects. In those that have, intraarticular temperatures in the shoulder, hip, knee, and ankle vary between 32.4°C (SD, 0.5°C) and 32.9°C (SD, 0.9°C)[17-20] (Table 2).

We recently evaluated the effects of several applications on the skin surface temperature and intraarticular temperature of the knee joint in 42 healthy volunteers. Mean skin surface temperature dropped by 16.4°C (SD, 3.6°C) after application of ice chips and by 15.0°C (SD,

Table 1: Effects of Physiotherapy in Animals In Vivo

Modality	Reference	Animal Model	Change in Tissue Temperature (°C)	Change in Muscle Temperature (°C)	Change in Intraarticular Temperature (°C)
Normal joints; cold treatment					
Ice	Wakim et al[12]*	Dog	−16.6	−17.4	−18.4
Ice	McMaster et al[15]†	Canine		−11.3	
Cold pack	Kern et al[14]‡	Bull			−6.6
Colc pack	McMaster et al[15]†	Canine		−8.4	
Chemical pack	McMaster et al[15]†	Canine		−3.5	
Freon pack	McMaster et al[15]†	Canine		−1.7	
Normal joints; heat treatment					
Hot pack	Wakim et al[12]*	Dog	+6.8	+4.0	+4.1
Microwave	Wakim et al[12]*	Dog	+4.9	+3.0	+6.0
Short-wave	Wakim et al[12]*	Dog	+2.9	+2.4	+2.8
Short-wave	Wakim et al[12]*	Dog	+4.1	+1.9	+3.3
Ultrasound	Lehman et al[13]§	Hog	+5.2	+3.7	+1.6
			+5.6		
			+8.2		
Ultrasound	Lehman et al[13]§	Hog	+4.1	+3.4	
			+6.4		
			+9.3		
			+2.3		
Adjuvant arthritis					
Ice	Dorwart et al[11]‖	Dog			−1.7
Hot pack	Dorwart et al[11]‖	Dog			+0.6

*Measurements in subcutaneous tissues, adjacent muscles, knee joints of dogs.

†Measurements in thigh muscles of canines.

‡Measurements in carpal joints of young bulls.

§Measurements in subcutaneous tissues, adjacent muscles, and knee joints of hogs.

‖Measurement in knee joints of dogs.

Table 2: Intraarticular Temperature

Subjects	Reference	Overall*	Knee
Healthy	Haimovici et al[17,20]	32.8 (0.8)	32.8 (1.1)
Healthy	Oosterveld et al[18]		32.5 (1.8)
Healthy	Horvath et al[19]		32.4 (0.5)
RA	Haimovici et al[17,20]	35.9 (1.4)	35.8 (1.5)
RA	Oosterveld et al[37]		35.6 (1.6)
RA	Horvath et al[19]		34.1 (1.6)
OA	Haimovici[20]	33.0 (0.9)	32.9 (0.9)
Active OA	Horvath et al[19]		34.4 (0.5)
Active OA	Haimovici[20]	36.0 (1.0)	36.1 (1.2)
Posttraumatic arthritis	Haimovici[20]	35.1 (1.3)	35.2 (1.4)

NOTE. Mean (SD) temperature in degrees C.
Abbreviations: RA, rheumatoid arthritis; OA, osteoarthritis.
*Mean (SD) temperature in shoulder, hip, knee, and ankle.

3.6°C) after application of nitrogen cold air. Mean intraarticular temperature decreased by 9.4°C (SD, 2.1°C) and 4.1°C (SD, 0.9°C), respectively. Treatment with lignoparaffin increased the surface temperature by 2.4°C (SD, 1.7°C) and temperature within the joint by 1.4°C (SD, 1.3°C).[18]

Further studies of the effects of locally applied heat and cold on surface temperatures, underlying soft tissues, and muscles are summarized in Table 3.[21-28] A correlation ($r = .81$) was found between body fat mass and lowest intramuscular temperature reached during cold treatment.[28]

Temperatures of forearm muscles are markedly influenced by ambient temperature after cooling for 15 minutes with a cooling agent at 10°C.[29] Muscle temperatures decreased in both treated (−2.7°C) and untreated (−2.0°C) forearms of research subjects. However, at an ambient temperature of 25°C, mean muscle temperature also decreased by 2.2°C and 2.1°C in the forearms of control subjects.

Studies of changes in blood flow during cold treatment have yielded contradictory results: significant increase,[30] significant decrease,[26] and absence of significant change[31] have been reported. Blood flow does not seem to be altered during short-wave diathermy or infrared treatment.[31]

The pain threshold of healthy subjects is increased by both heat and cold.[27,32] Joint stiffness is increased by cold[33] and decreased[33] or unchanged[34] by heat.

STUDIES IN PATIENTS WITH RA AND OA

Temperature in Joints and Skin

In 1949, Hollander and Horvath published their first results on intraarticular temperature measurements.[19,35,36] Forty-two internal temperature determinations in the knee joint and overlying skin surface and two in elbow joints were obtained in 31 arthritis patients and four controls. In the presence of active RA, the highest joint temperature was 37.4°C and the highest surface temperature was 35.6°C. Mean temperatures were 34.1°C (SD, 1.6°C) and 32.7°C (SD, 1.8°C), respectively. In OA, the mean surface temperature was 32.2°C (SD, 1.1°C) and mean joint temperature was 34.4°C (SD, 0.5°C). A correlation ($r = .65$) was found between recorded surface and intraarticular temperatures. Comparable results were found by others in synovitis,[19,20] OA,[20] and RA[17,19,20,37] (Table 2).

Influence of Movement

The effects of active and passive non–weight-bearing motion on joint temperature have been reported in three studies.[19,35,36] In two healthy subjects, mean intraarticular temperatures increased by 0.7°C. In one case of degenerative joint disease, an increase of 0.7°C was found. Five measurements in RA patients yielded an average temperature increase of 0.3°C.[36]

Influence of Applications

Experimental studies in RA patients show that locally applied heat increases and cold decreases the temperature at the skin surface and in superficial tissue.[26,38] However, there is controversy concerning the effects on intraarticular temperature.

Heating the lower extremities with infrared radiation for 30 minutes results in a slight increase in joint temperature.[35] Short-wave diathermy for 20 minutes increases surface temperature more than intraarticular temperature. Mean increases of 4.3°C and 3.2°C in the joint and 5.4°C and 4.0°C on the surface have been observed.[35,36] After 15 minutes of microwave treatment, joint temperature increased by 4.0°C in one study[35] and 2.9°C in another,[36] and surface temperature increased by 3.1°C and 2.8°C.

Application of hot packs for 4 minutes invariably results in an increase in surface temperature and a decrease in intraarticular tempera-

Table 3: Effects of Physiotherapy in Healthy Subjects

Modality	Reference	Change in Skin Temperature (°C)	Change in Tissue Temperature (°C)	Change in Muscle Temperature (°C)	Change in Intraarticular Temperature (°C)	Blood Flow	Pain Threshold	Joint Stiffness
Ice	Oosterveld et al[18]	−16.4†			−9.4†			
Ice	Belitsky et al[24]	−12.0						
Ice	Belitsky et al[24]	−9.9						
Ice	Waylonis[25]	−19.2						
Ice	Bugaj[27]	4.0/39.4*					+	
Ice	Wyper et al[31]					+		
Ice	Benson et al[32]							+
Nitrogen	Oosterveld et al[18]	−15.0†			−4.1†			
Cold pack	Schmidt et al[23]	−12.0						
Cold pack	Belitsky et al[24]	−7.3						
Cold pack	Beste et al[26]	−6.0				−†		
Cold pack	Wolf[29]			−2.7				
Cold pack	Trnavsky[30]					+§		
Cold water	Johnson et al[28]			−12.0‡				
Ice water	Wright et al[33]							+
Short-wave	Oosterveld et al[18]	+2.4†			+1.4†			
Short-wave	Abramson et al[22]	+1.3	+1.5	+1.9				
Short-wave	Wyper et al[31]					+		
Short-wave	Benson et al[32]						+	
Lignoparaffin	Oosterveld et al[18]	+8.9†			+3.5†			
Paraffin	Borrell et al[21]			+4.5	+7.5			
Paraffin	Abramson et al[22]	+13.0	+4.4	+1.0				
Paraffin	Abramson et al[22]	+13.5	+6.2	+3.2				
Paraffin	Abramson et al[22]	+13.0	+5.5	+2.4				
Fluido	Borrell et al[21]			+5.3	+9.0			
Hot water	Borrell et al[21]			+4.3	+6.0			
Heat pack	Abramson et al[22]	+10.2	+5.3	+1.1				
Wet heat	Abramson et al[22]	+6.4	+5.4	+1.8				
Ultrasound	Abramson et al[22]	+0.9	+1.4	+0.9				
Hot pack	Schmidt et al[23]	+3.0						
Infrared	Wyper et al[31]					=		
Infrared	Wright et al[33]							−
Heat	Yung et al[34]							=

*Mean temperature measured at the end of treatment.
+, insignificant increase; −, insignificant decrease; =, no change.
†$P \leq .01$.
‡$P \leq .05$.
§$P \leq .001$.

ture. Application of ice packs for the same time increased joint temperature; maximum changes occurred within the first 2 minutes.[19] Surface heating was believed to decrease intraarticular temperature by shunting blood to the dilated superficial vessels and away from the inflamed synovial tissue; surface cooling did the reverse. Applying warm paraffin to joints for 25 minutes caused a sharp increase in surface temperature and a delayed but marked increase in temperature within the joint[36] (Tables 4 and 5).

Later studies have produced results that are at least partially incompatible with those just described. In one, a magnetrode (a machine capable of heating deep tissue by means of an electromagnetic field) was used to treat five patients with classical RA and active inflammation of the knee for 60 minutes. Mean intraarticular temperature increased from 36.6°C (SD, 0.8°C) to 42.0°C (SD, 0.9°C); mean surface temperature increased from 33.7°C (SD, 0.9°C) to 37.2°C (SD, 1.9°C).[39] Others found that

Table 4: Effects of Physiotherapy in Patients With Inflammatory Joint Disease—Cold Applications

Modality	Reference	Change in Skin Temperature (°C)	Change in Intraarticular Temperature (°C)	Blood Flow	Pain	Joint Stiffness	Inflammation Activity	Grip Strength	Joint Function
Cold pack	Beste et al[26]	−4.9		+					
Cold pack	Hollander et al[35]		+1.2						
Cold pack	Hollander et al[36]	−4.1	+1.2						
Cold pack	Schmidt et al[64]						−		
Ice massage	Grant[44]				−				+
Ice massage	Melzack et al[54]				−				
Cold air	Oosterveld et al[37]	−22.8†	−3.3†						
Cold air	Hoeft[45]	24.0/75.2*			−				=
Cold air	Hoeft[45]	23.5/74.3*			=				=
Cold air	Jansen et al[46]	−14.0			−				+
Cold air	Heijde et al[50]	−8.9†			−			+	
Cold air	Jonderko et al[51]				−				+
Ice	Oosterveld et al[37]	−16.2†	−6.4†						
Ice	Liman et al[42]	−		+					
Ice	Halliday Pegg et al[47]				−	−			=
Ice	Clarke et al[49]				−‡	−‡			+‡
Ice	Heijde et al[50]	−6.2†						+	
Ice	Kirk et al[52]				−	−	=		+
Ice	Bulgen et al[57]				−				+
Ice	Williams et al[59]				−				+
Cold	Arman et al[41]			−					
Cold	Klawunde[63]	20.0*							+

*Mean temperature measured at the end of treatment.
†, insignificant increase; −, insignificant decrease; =, no change.
†$P < .001$.
‡$P < .05$.

30-minute applications of hot packs at 42°C increased mean intraarticular temperature significantly from 35.2°C (SD, 1.5°C) to 36.4°C (SD, 1.0°C).[40] Surface and joint cavity temperatures did not return to their initial values until 55 minutes after heating stopped.

Recent investigations in our clinic yielded comparable results. Seventy-one measurements of intraarticular temperature in arthritic patients showed a significant increase of 1.7°C (SD, 1.2°C) after superficial lignoparaffin treatment, a decrease of 6.4°C (SD, 2.8°C) after application of ice chips, and a decrease of 3.3°C (SD, 1.6°C) after treatment with nitrogen cold air. In 6 of 19 measurements in the ice chips–treated group and in 6 of 17 measurements in the nitrogen-treated group, there was an initial increase in intraarticular temperature. In the lignoparaffin-treated group (n = 20), there was an initial decrease in intraarticular temperature in two cases. We observed no significant temperature changes during placebo treatment using a short-wave diathermy apparatus.[37]

Although evidence from the current literature is not unequivocal, intraarticular temperature appears to increase after application of local heat and decrease after application of local cold.

Clinical Effects of Application

The effects of heat and cold on blood flow through various tissues reported for patients with inflammatory joint diseases are as inconsistent as those reported for healthy subjects. Some have found that superficial heat increases blood flow and that local cold decreases it,[41] and others have found a slight increase in blood flow after or during cold application.[26,42] The effect of short-wave diathermy on circulation in quiescent rheumatoid knees (n = 13) and acutely inflamed joints (n = 5) also has been studied.[43] In quiescent arthritis, an average increase of

Table 5: Effects of Physiotherapy in Patients with Inflammatory Joint Disease—Heat Applications

Modality	Reference	Change in Skin Temperature (°C)	Change in Intraarticular Temperature (°C)	Blood Flow	Pain	Joint Stiffness	Inflammation Activity	Grip Strength	Joint Function
Short-wave	Hollander et al[35]	+5.4	+4.3						
Short-wave	Hollander et al[36]	+4.0	+3.2						
Short-wave	Endres et al[38]	+							
Short-wave	Clarke et al[49]				−§	−§			+§
Short-wave	Quirk et al[55]				−§				+§
Short-wave	Danz et al[60]	+§						+	
Short-wave	Hamilton et al[61]							+	+
Short-wave†	Harris[43]			−					
Short-wave‡	Harris[43]			+					
Short-wave	Svarcová et al[56]				−				
Microwave	Hollander et al[35]	+3.1	+4.0						
Microwave	Hollander et al[36]	+2.8	+2.9						
Infrared	Hollander et al[35]		+						
Infrared	Hollander et al[36]	+3.9	+1.7						
Infrared	Hamilton et al[61]							+	+
Hot pack	Weinberger et al[40]	+2.4‖	+1.2‖						
Hot pack	Hollander et al[35]		−1.2						
Hot pack	Hollander et al[36]	+3.9	−0.4						
Hot pack	Kirk et al[52]				−	−	=		+
Paraffin	Hollander et al[35]	+	+						
Paraffin	Hollander et al[36]	+6.2	+1.1						
Paraffin	Oosterveld et al[37]	−7.5¶	+1.7¶						
Magnetrode	Spiegel et al[39]	+3.5	+5.4						
Mud pack	Zivkovic et al[48]				−		−		+
Heat	Mainardi et al[53]				−		=	−	
Ultrasound	Svarcova et al[56]				−				
Ultrasound	Hawkes et al[58]				−§			+§	+§
Wax	Hawkes et al[58]				−§			+§	+§
Wax	Hamilton et al[61]							+	+
Moist heat	Williams et al[59]				−				+
Thermal bath	Günther et al[62]								+
Heat	Arman et al[41]			+					

+, insignificant increase; −, insignificant decrease; =, no change.
†Measurement in acutely inflamed joints.
‡Measurements in quiescent arthritic joints.
§$P < .05$.
‖$P < .01$.
¶$P < .001$.

60% was found. Acutely inflamed joints showed a mean decrease of 25%. A 100% increase was found in eight normal subjects.

The beneficial influence of heat and cold on pain in joint disease is well established.[44-59] Results of relevant studies are summarized in Tables 4 and 5.

Joint stiffness improves after local applications of heat or cold.[47,49,52] Grip strength usually improves with thermotherapy or cryotherapy.[50,53,58,60,61]

The effect of heat applications on joint function has been examined in several studies, and improvement has been reported in nearly all cases.[48,49,52,55,58,59,61,62] Some authors have described improvement[44,46,49,51,52,57,59,63] or no change[45,47] in joint function after cold applications.

Influence on Pathology

There have been few studies of the influence of heat and cold on the pathology of the

inflamed joint. Kirk and Kersley[52] and Mainardi et al[53] showed that neither heat nor cold had any effect. Others have found a decrease in inflammation after 1 week of applying cryogel twice a day[64] or after a series of 10 applications of warm mudpacks.[48]

DISCUSSION

Enzymatic activity increases with increasing temperature, resulting in increased breakdown of cartilage and other tissues.[65] Therefore, treatments that elevate intraarticular temperature, such as microwave diathermy, short-wave diathermy, superficial heat, and ultrasound treatment, are unsuitable for treating active arthritis or secondary synovitis in OA.[65-67] Because higher temperatures lead to joint damage, a major aim of physiotherapeutic procedures in active arthritis should be to decrease joint temperature.[4,68] This can be achieved with local applications of cold lasting 20 to 30 minutes.[69,70]

The increased extensibility of collagen tissue at higher temperatures suggests that lost joint mobility may be regained.[65,71-75] The viscoelasticity of the synovial fluid also is influenced by heat.[76,77] Both effects can lead to reduction in stiffness of inflamed joints, as experienced by those who wear gloves at night.[78,79]

In our opinion, the reported beneficial effects of cold treatment on joint stiffness and joint function are strongly related to relief of pain during or after cryotherapy. Movements may be less painful and therefore easier to perform.

It was recently suggested that heating the joint cavity to 42°C with local microwave diathermy might inhibit destructive enzymes and cell proliferation in and metabolic activity of the synovial membrane. The increased permeability of the synovial membrane for nonsteroidal anti-inflammatory drugs also might be beneficial.[80] This hypothetical benefit is tempered by the finding that irreversible damage occurs in canine ligaments at this temperature.[10]

Treatment of RA patients using whole-body hyperthermia has been reported,[71,76,81] but this therapy currently is not used in Western Europe. There are claims that whole-body hyperthermia is harmful to RA patients and that whole-body cryotherapy is preferable.[82] These studies are controversial and incomplete.

CONCLUSIONS

Locally applied heat increases temperatures of the skin, superficial and deeper tissues, and joint cavity. In arthritic patients, an initial decrease in intraarticular temperature lasting 2 or 3 minutes sometimes is seen after local superficial application of heat.

Local cold application decreases temperatures of the skin, superficial and deeper tissues, and joint cavity. In arthritic patients, an initial increase in intraarticular temperature lasting 2 or 3 minutes sometimes is seen after local application of cold.

Locally applied heat and cold both reduce pain in inflammatory joint disease. Grip strength, joint stiffness, and joint function usually improve after local heat or cold therapy. The beneficial effects of exercise may be enhanced if some form of heat or cold is applied to joints and muscles beforehand; more research in this field is needed.

Joint temperature increases during movement.

It is unclear what effects heat and cold have on inflammation and blood flow in joints.

In treating active arthritis, cold applications are preferable because an increase in intraarticular temperature is undesirable. If the patient nevertheless prefers heat, as is sometimes the case, heat application should last no more than 5 to 10 minutes.

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