

Cryotherapy

Physical Principles

- the principal mode of energy transfer for therapeutic cooling is through *conduction*
- direct interaction of molecules in warmer area with those in cooler area causes energy gain of the cooler/slower particles and energy loss of warm/faster particles
- the rate of heat transfer by conduction is the following:

$$D = \frac{\text{area} \times k \times (T1 - T2)}{\text{thickness of tissue}}$$

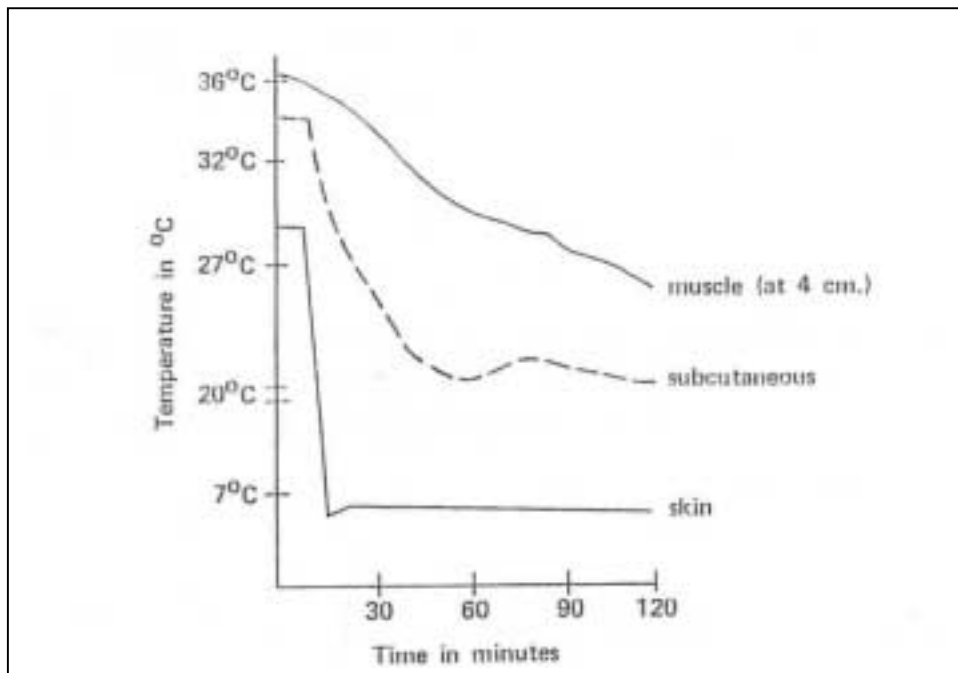
D: rate of heat loss (cal/s)

area: amount of body surface area cooled or heated

k: thermal conductivity of tissue (cal/s/cm²×°C/cm²)

T1/T2: temperatures of warm and cool surface (°C)

- ∴ the greater the temp. gradient b/w the skin and cooling source ➔ the higher the rate
- note from figure below: the deeper the tissue ➔ the longer time needed to ↓ temp.



- need ~30 min. to ↓ muscle temp. at a depth of 4 cm by 3.5°C

-the higher the *fat content*, the slower the rate of energy transfer b/c adipose tissue acts as an insulator (∴ longer to cool muscle and longer for muscle to return to normal temp.!!)
 -level of activity can influence return of temp. to pre-cooled levels

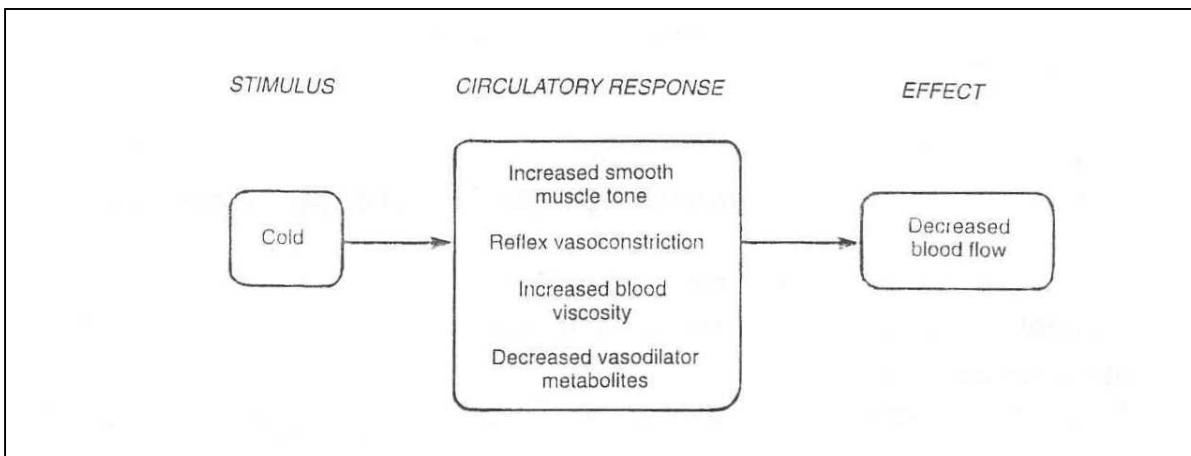
*If exercise performed after cooling ➔ ↑ blood flow to area ➔ faster rewarming

Biophysical Principles of Tissue Cooling

-cold used in management of ACUTE trauma (24-48 hours after) b/c it causes:

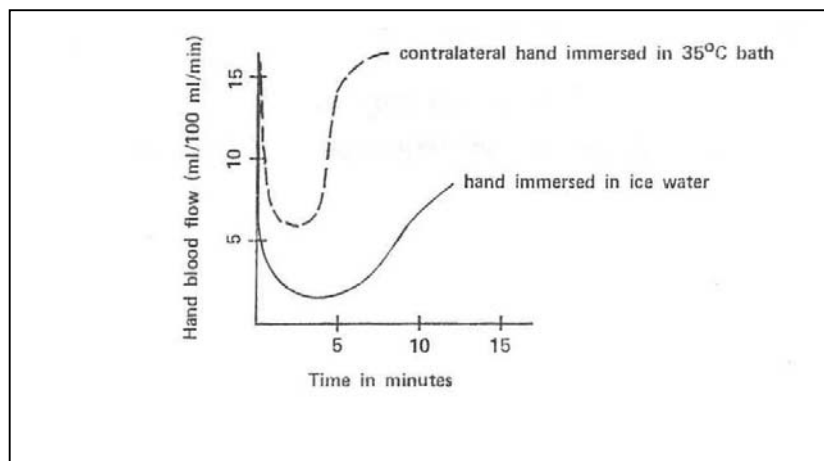
- 1) vasoconstriction (d/t direct action of cold on smooth muscle tone and reflex cutaneous vasoconstriction) ➔ **reduces bleeding**
- 2) ↓ in metabolism ➔ ↓ **secondary hypoxic injury and ↓ inflammation**
- 3) ↓ vasoactive agents (eg. histamine) ➔ ↓ **fluid filtration to interstitium (↓ inflammation)**
- 4) ↑ of pain threshold (counterirritant) ➔ ↓ **pain**

Hemodynamic Effects



-the *reflex vasoconstriction* (part of heat retention mechanism of body triggered by cold thermal sensors) can also result in generalized cutaneous vasoconstriction

-BUT, ↓ in blood flow greatest in the area directly cooled



Hunting Response

-when tissue temp. reduction maintained for long time (> 15 min.), or when temp. <10°
 ➡ cold induced *vasodilation* (skin temp. ↑'s)

-then, there are cyclic periods of vasoconstriction and vasodilation

-during these cyclic periods, temp. never returns to normal

-explanation: I)temp. drops <10° ➡ release of substance "H" a neurotransmitter (similar to histamine)

 ➡ vasodilation

 II)warm blood into area ➡ tissue temp. goes >10°

 ➡ vasoconstriction
 (the ice is again effective)

 III)cycle continues.....

**cold vasodilation* can also occur w/o the hunting (cycling) response

-demonstrated in an experiment where the human forearm was cooled at 1 °C

-there was an ↑ in blood flow after 15 min.!!

-only slight ↑ in blood flow when cooled with temperatures at 10°C

-vasodilation was thought to be a deep response (skeletal muscle) & local (no change on contralateral extremity)

Effects on Peripheral Nerves

-both *conduction velocity* and *synaptic activity* of peripheral nerves can be altered by cold

-why? when nerves are cooled, synaptic transmission can be impeded or blocked

-some postulate that it alters the transmembrane ionic flow

CAUTION: -ice application resulted in four cases of neuropraxia and one of axonotmesis in young athletes

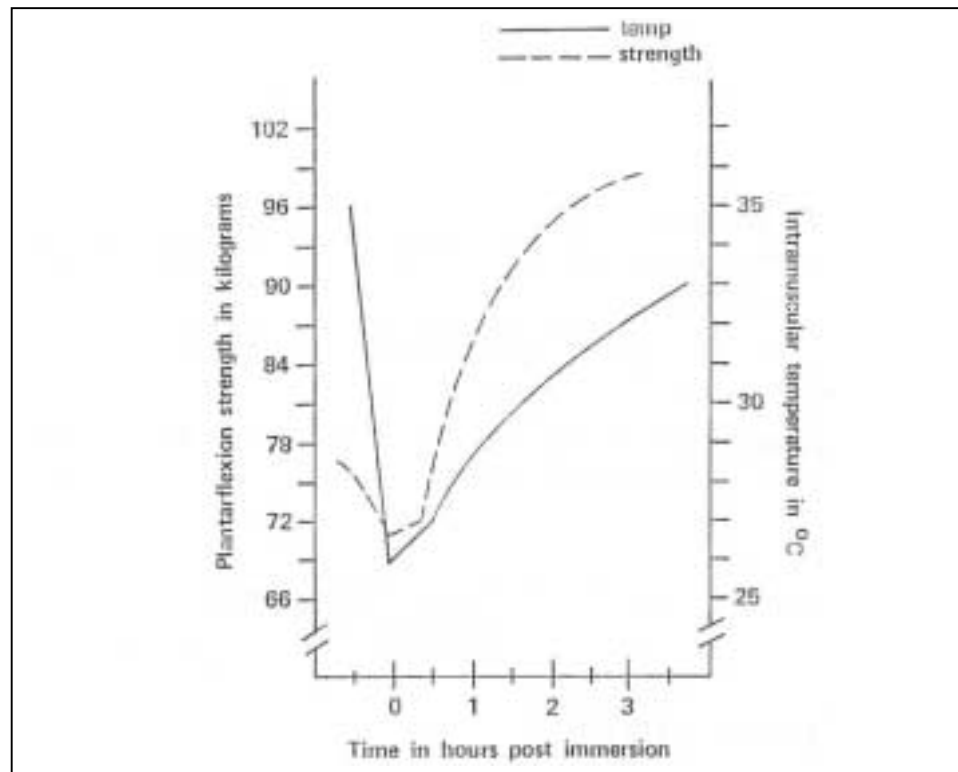
-the ice packs were applied over a superficial br. of a major nerve (peroneal n. below knee or around the thigh for upto 2 hours!!!)

Muscle Strength

-there have been reports of 30min. of cold exposure to 10°C decreased strength (of grip and plantorflexors)

-most likely d/t ↓ in *blood flow* and ↑ in *viscous properties* of the muscle

-therefore, strength evaluation should be done before cold application!



Neuromuscular Effects

- cryotherapy can temporarily reduce *spasticity* [spasticity = ↑↑'d resistance to passive stretch, ↑↑'d deep-tendon reflex (DTR) and clonus]
- it decreases the amplitude of the DTR and the freq. of clonus

Mechanism: -cold facilitates alpha-motoneuron activity and decreases gamma-motoneuron firing

- gamma-motoneuron decreased through stimulation of cutaneous afferents (∴ reflex)
- there is also a decrease in the afferent-spindle discharge by direct cooling of the muscle

Clinical Indications

1) Musculoskeletal Trauma

- this includes postorthopedic surgical swelling and pain (eg. TKA)
- reduction of analgesics intake following cold has been reported by some
- cold with compression controls swelling better than compression alone

Duration

- cold applied for durations of 15 minutes several times a day, in conjunction with elevation and compression

-if applied over a cast, apply for longer

2) Myofascial Pain Syndrome

-def'n: pain and/or autonomic phenomena referred from active myofascial trigger points with associated dysfunction

-trigger point ➡ from muscular strain and may be assoc. w/ sensitive nerves, ↑↑'d metabolism and ↓↓'d circulation

➡ can be treated with ice massage, deep pressure, ultrasound, electrical stimulation and low-power laser

3) Reduction of Spasticity

-use cryotherapy to reduce the hypertonicity to allow for purposeful mov't and activity

-apply cold over hypertonic muscle for 10-30 minutes

Methods of Cryotherapy

1) Cold packs

2) Ice massage (over a small area)

3) Cold baths (for an entire extremity)

4) Vapocoolant Spray

subjective feeling to cryotherapy: intense cold, burning, aching, then analgesia

Contraindications

1) Cold urticaria

-in response to cold, pt. develop bumps on skin that are red and swollen

-due to mast-cell degranulation ➡ release of histamine

-in severe case, pt. has generalized swelling of mucous membranes and viscera

-can even have systemic reactions: ↓ blood pressure, ↑ heart rate and syncope

2) Cryoglobulinemia

-pt. has an abnormal blood protein that forms a gel when exposed to low temp.'s

-gel formation can lead to ischemia or gangrene

3) Raynaud's phenomena

-a vasospastic disorder brought on by exposure to cold or by emotional stress

-cycles of pallor, cyanosis, rubor, and normal color of the fingers may be accompanied by numbness, tingling or burning

4) Paroxysmal cold hemoglobinuria

-d/t local or general exposure to cold

-hemoglobin is released from lysed red cells and appears in the urine

5) Peripheral vascular disease

-affects arterial circulation, and the vasoconstrictive effects of cold could make things worse!

-in general, don't use cold over areas of compromised circulation

Precautions

-hypersensitivity to cold, thermoregulatory disorders, wound healing (b/c blood flow ↓'d by cold), superficial nerves, psychological response

Superficial Heating

Biophysical Principles

-the occurrence and magnitude of the *physiologic changes* depend upon:

1) Extent of temp. rise

➤ tissue temp. should be raised b/w 40°C to 45°C so that hyperemia (↑'d blood flow) can occur

➤ above this range, potential for tissue damage!!

2) Rate at which energy is being added to tissue

➤ if too slow, amount of heat added could be balanced out by the convective effect of cooler blood

➤ if too fast, heat may build up to a point that stimulates pain receptors

➤ goal of heating is to achieve a therapeutic level of temp. ↑ w/o damaging tissue!

3) Volume of tissue exposed

➤ the larger the tissue vol., the ↑ the likelihood for reflex changes in other areas and systemic changes

Facts

-greatest degree of temp. ↑ w/ superficial heating: in the skin and subcutaneous tissues within 0.5cm deep

- muscle temp. at depth of 1-2cm will require a longer duration of exposure (15-30 minutes and will result in smaller temp. \uparrow)
- at depth 3cm \Rightarrow expect a **1°C increase** (or less) using clinically tolerable intensities
- fat provides insulation against heat $\Rightarrow \therefore$ must use deep heating device (diathermy or continuous ultrasound) to raise temp. in deeper tissues.

Metabolic Reactions

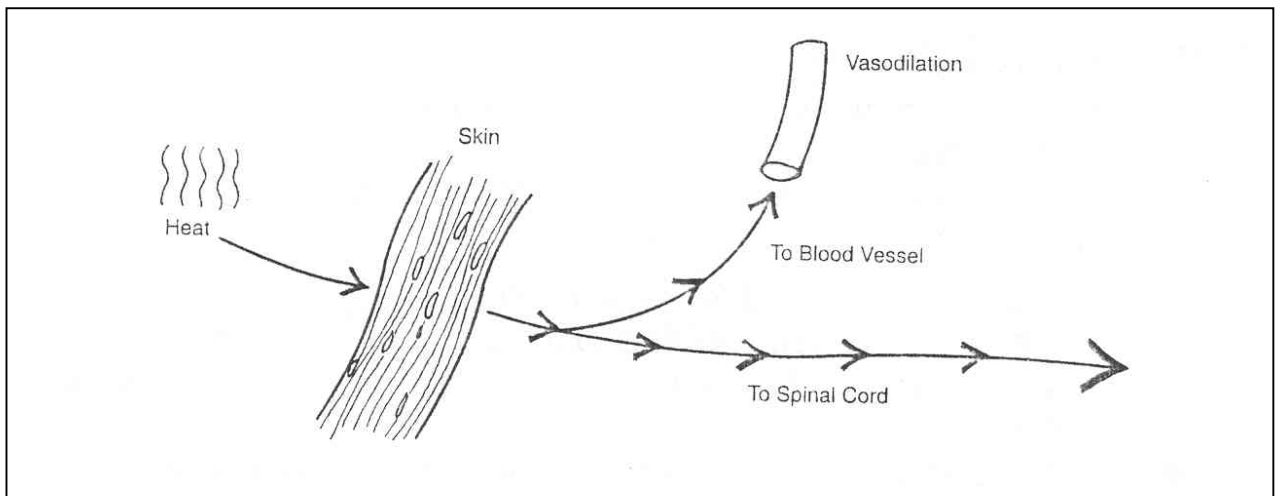
- metabolic rate* will \uparrow 2 \times or 3 \times for each 10°C rise in temp.
- \Rightarrow the good: O₂ uptake will \uparrow and more nutrients will be available to *promote healing*
- \Rightarrow the bad: tissue will *burn* >45-50° b/c ++protein denaturation exceeds ability to repair tissue

Vascular Effects

-*vasodilation* of the heat-exposed skin occurs d/t 3 factors:

1) An axon reflex

- heat stimulates cutaneous thermoreceptors \Rightarrow afferent signals go to spinal cord \Rightarrow some afferents go towards blood vessels \Rightarrow vasoactive mediators released \Rightarrow vasodilation

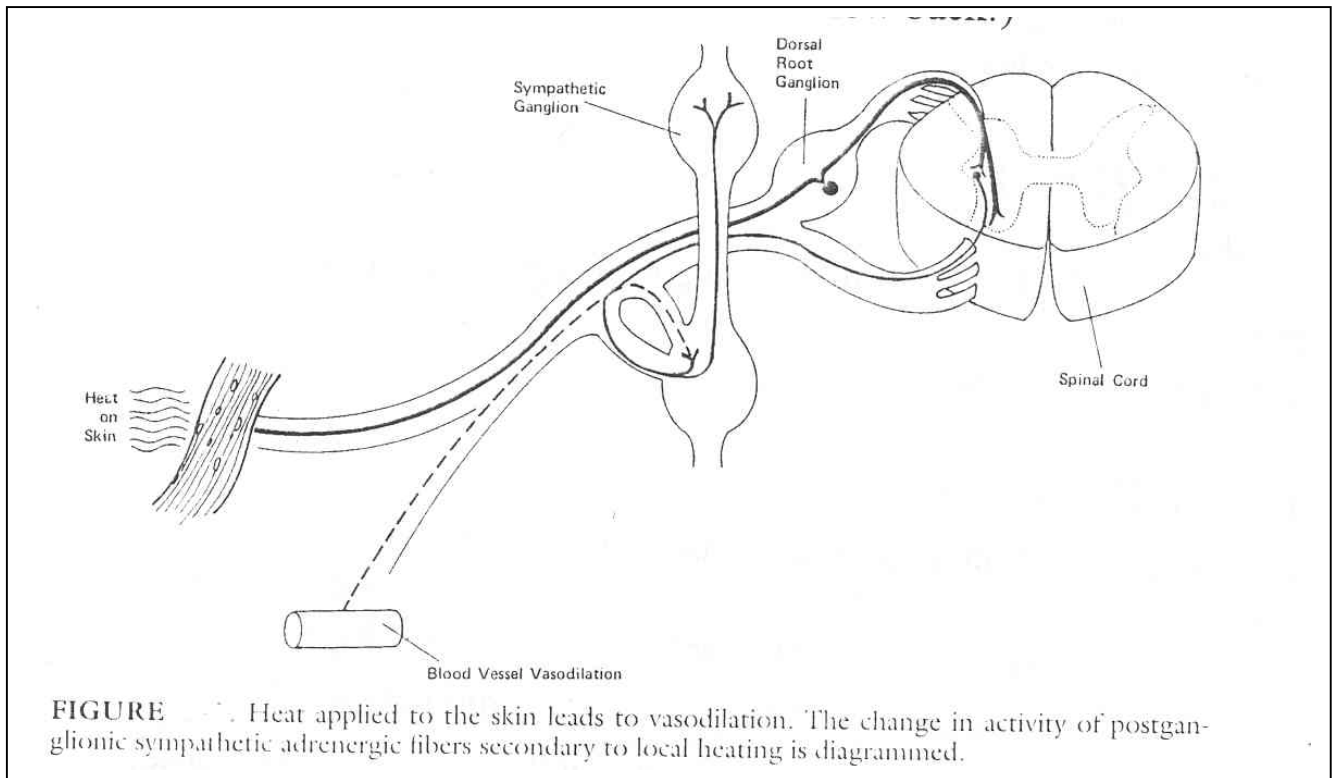


2) Release of chemical mediators

- heat produces a mild inflammatory rxn \Rightarrow release of histamine and prostaglandins and bradykinin
- they act on smooth-muscle tone and endothelial-cell contractility to cause vasodilation of vessels and \uparrow capillary permeability

3) Local spinal cord reflex

- causes a ↓ in nerve activity to the smooth muscles of blood vessels
- ∴ there can be changes in areas far from the site of application (eg. ↑ blood flow to feet could be caused by application of heat to the low back!)



Skeletal blood flow

- primarily under metabolic regulation ➡ ∴ shows greatest response to EXERCISE!!!
- with superficial heating ➡ minimal to no changes in skeletal muscle blood flow
- order of blood flow increase: heat < exercise < combination of heat&exercise

Neuromuscular Effects

- heat is used therapeutically to provide *analgesia* by increasing the pain threshold
 - ➡ ∴ it can be used to reduce pain before stretching, joint mobilizations and active exercise
- heat can also ↓ *muscle spasms* (be sure not to place muscle in a pos'n of undue stretch)
 - Explanation: ➡ produces a ↓ in gamma efferent activity, thus the stretch on the muscle spindle is less
 - ➡ afferent firing from the spindle reduced

- ➔ indirectly, this ↓'s alpha-motoneuron firing
- ➔ less spasm

Connective Tissue Effects

- heat and stretch of connective tissue will result in *plastic deformation* (residual elongation)
- less damage* is also suffered if stretch applied when tissue temp. is elevated
- heating can also result in decreased *joint stiffness* and ↑'d tissue extensibility (be sure to place joint in an open-packed position so that the intra-articular pressure and stress on joint structures will be less.)

Heating Agents

1) Hot packs

- be sure to cover the hot pack with layers of towel (if not, I smell a law-suit!!)

2) Paraffin Wax

- used for distal extremities

Contraindications

- over areas w/ a lack of intact thermal sensation (risk of burn)
- over areas of vascular insufficiency or vascular disease (poor circulation➔burn!)
- over areas of recent/potential hemorrhage (heat will ↑↑ bleeding)
- over areas of known malignancy (it may ↑↑ mov't of malignant cells)
- over areas of acute inflammation (it may potentially ↑↑ inflamm. response)
- over infected areas (it may spread infection to other areas)
- in situations deemed unreliable by therapist (eg. pt. doesn't speak english, thus won't understand therapist instructions puts them at risk)

Contrast Bathing

- used in the treatment of chronic swelling of distal extremities to promote local circulation through its cyclical vasodilation (heat) and vasoconstriction (cold) effects (although NOT well researched!)
- have been advocated for: arthritis of peripheral joints, joint sprains, muscular tenderness strains, some peripheral vascular disease, and to toughen amputation stumps
- requires the use of two basins of water: hot (temp. from 38-44°)
cold (temp. from 10-18°)
- basins should be large enough to enable immersion of the extremity to cover at least the level of injury
- method: warm for 10min, cold for 1min. then hot for 4 min. for a total of 30 min.

- generally accepted hot:cold ratio is 3:1 or 4:1
- however, some clinicians may use a 1:1 ratio as well (1 min. hot, 1 min. cold)
- contraindications: diabetes (small-vessel vascular disease), arteriosclerotic endarteritis, Buerger's disease

**No well-controlled studies discussing the efficacy of contrast baths available in the literature.

Summary

HEAT VS COLD			
Heat		Cold	
<i>Advantages:</i> ↓ pain ↑ tissue extensibility ↓ stiffness	<i>Disadvantages:</i> May cause ↑ swelling	<i>Advantages:</i> May prevent further swelling ↓ pain	<i>Disadvantages:</i> ↑ stiffness ↓ tissue extensibility

Question: Does it take a cooled area longer than a heated area to return to precooled temperatures?

Answer: YES! Cold ➡ vasoconstriction of arterioles ➡ decrease the amount of warm blood flowing into the area ➡ ↓ countercurrent heat exchange ➡ slow rate of rewarming

Further Readings

- 1) Uchio et al.
Cryotherapy influences joint laxity and position sense of the healthy knee joint.
Arch Phys Med Rehabil 2003;84:131-5.

- 2) Chesterton et al.
Skin temperature response to cryotherapy.
Arch Phys Med Rehabil 2002;83:543-9.

- 3) Jutte et al.
The relationship between intramuscular temperature, skin temperature and adipose during cryotherapy and rewarming.
Arch Phys Med Rehabil 2001;82:845-50.

- 4) Thermotherapy for treating rheumatoid arthritis
Cochrane Library (Oxford) (3):2002.