Cryotherapy

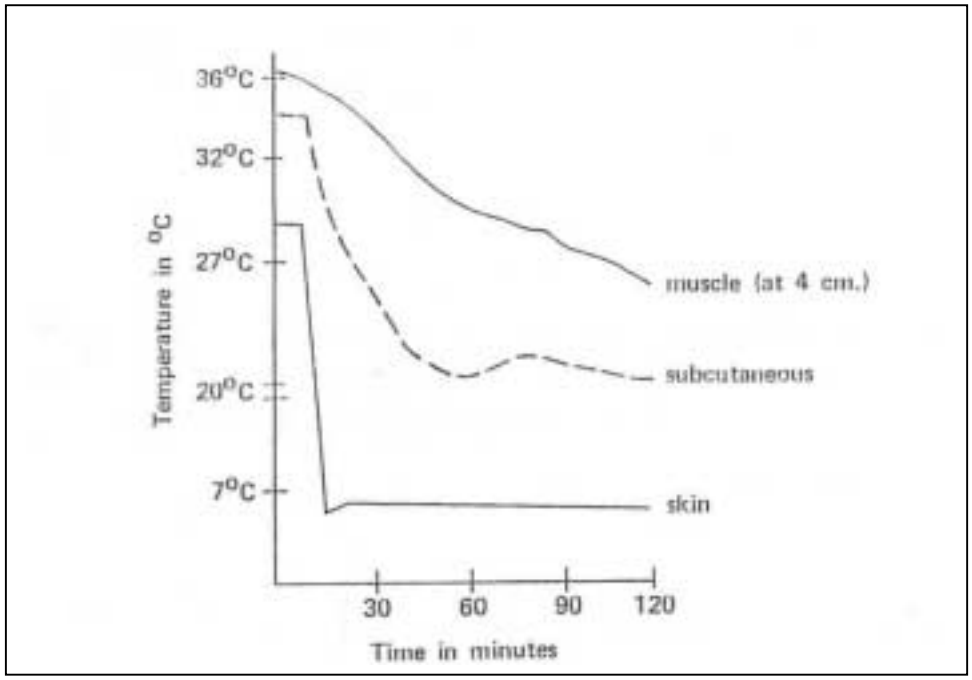
Physical Principles

-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/cm^2×°C/cm^2)
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

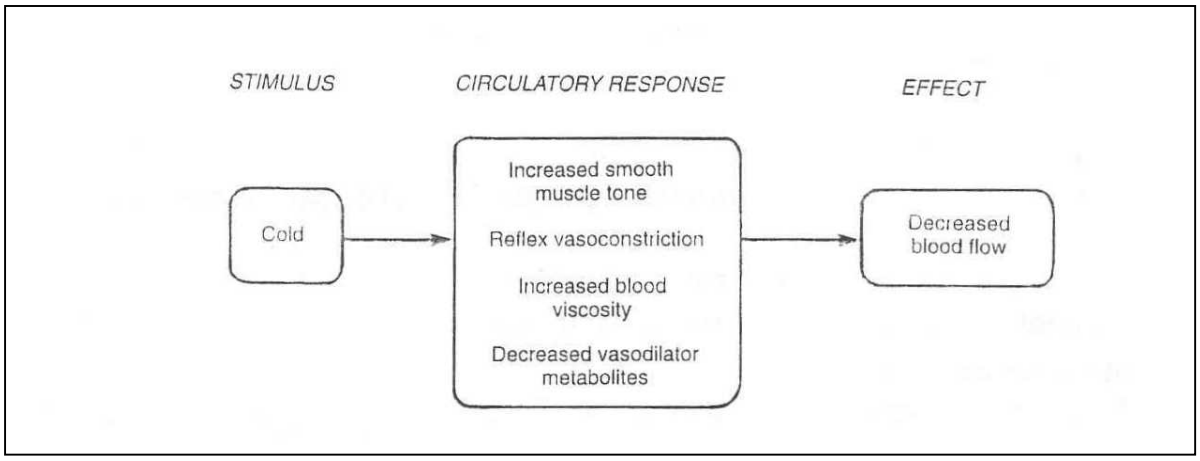
-the higher the *fat content*, the slower the rate of energy transfer b/c adipose tissue acts as an insulator (∴ longer to cool muscle and longer for muscle to return to normal temp.!!)
-level of activity can influence return of temp. to precooled levels
*If exercise performed after cooling ➡ ⇑ blood flow to area ➡ faster rewarming

Biophysical Principles of Tissue Cooling

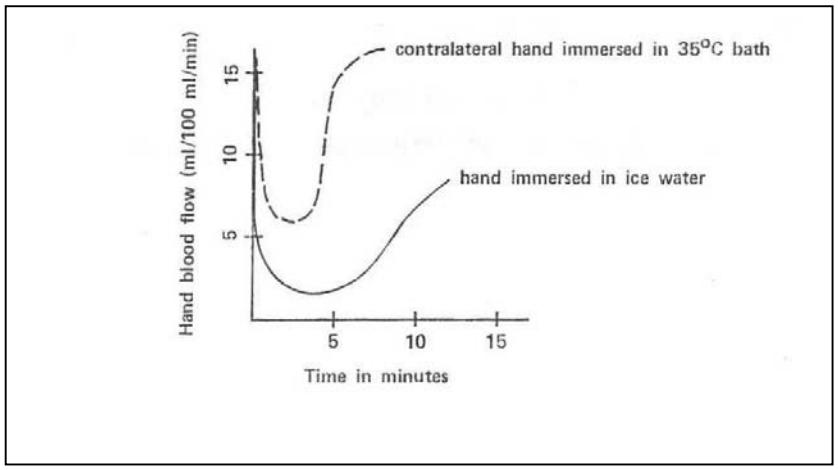
-cold used in management of ACUTE trauma (24-48 hours after) b/c it causes:

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 Respo nse

-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 <u>vasoconstriction</u> and <u>vasodilation</u>
-during these cyclic periods, temp. never returns to normal
-<u>explanation</u>: 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.....

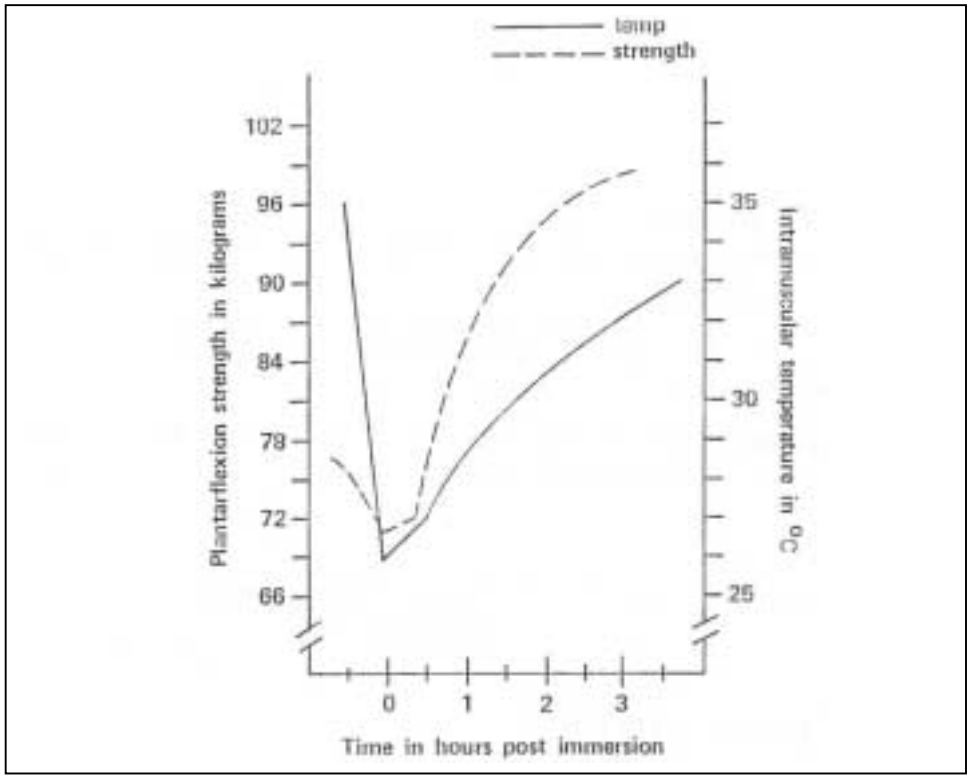
**cold vasodilation* can also occur w/o the hunting (cycling) response
-demonstrated in an experiment where the human forearm was cooled at 1°C
-there was an ⇑ in blood flow after 15 min.!!
-only slight ⇑ in blood flow when cooled with temperatures at 10°C
-vasodilation was thought to be a <u>deep response</u> (skeletal muscle) & <u>local</u> (no change on contralateral extremity)

Effects on Peripheral Nerves

-both *conduction velocity* and *synaptic activity* of peripheral nerves can be altered by cold
-<u>why</u>? when nerves are cooled, synaptic transmission can be impeded or blocked
-some postulate that it alters the transmembrane ionic flow
<u>CAUTION</u>: -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 <u>2 hours</u>!!!

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 cutaneuous 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 message, 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. ⇑)
-at depth 3cm ➨ expect a **1°C increase** (or less) using clinically tolerable intensities
-fat provides insulation against heat ➨ ∴ must use deep heating device (diathermy or continuous ultrasound) to raise temp. in deeper tissues.

Metabolic Reactions

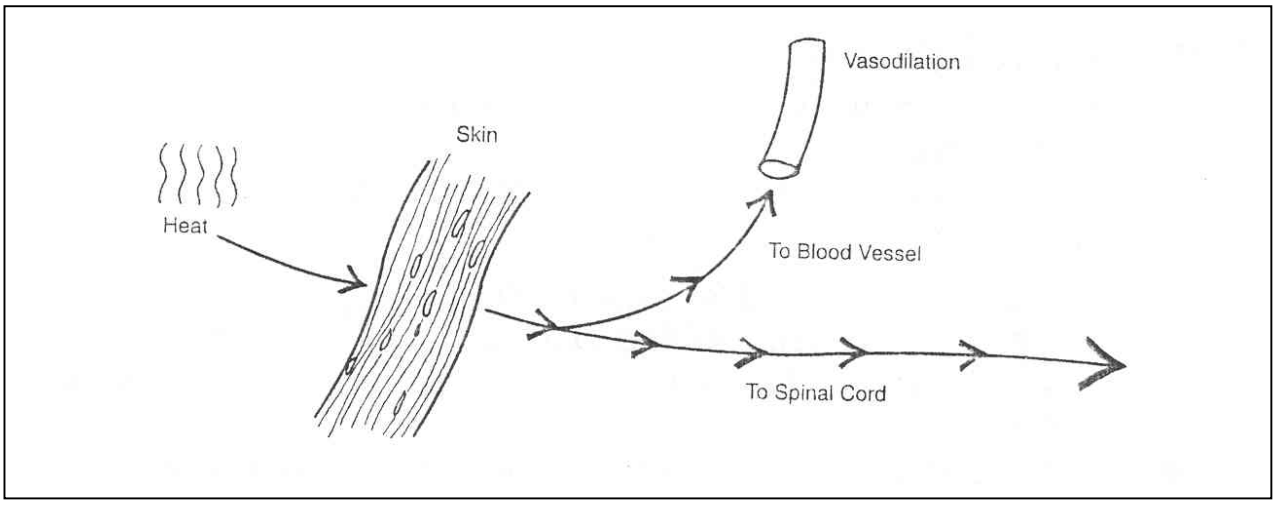
-*metabolic rate* will ⇑ 2× or 3× for each 10°C rise in temp.
➨the good: O_2 uptake will ⇑ and more nutrients will be available to *promote healing*
➨the bad: tissue will *burn* >45-50° b/c ++protein denaturation exceeds ability to repair tissue

Vascular Effects

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

1) An axon reflex

-heat stimulates cutaneuous thermoreceptors ➨ afferent signals go to spinal cord ➨ some afferents go towards blood vessels ➨ vasoactive mediators released ➨ vasodilation



2) Release of chemical mediators

-heat produces a mild inflammatory rxn ➨ release of histamine and prostaglandins and bradykinin
-they act on smooth-muscle tone and endothelial-cell contractility to cause vasodilation of vessels and ⇑ 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!)

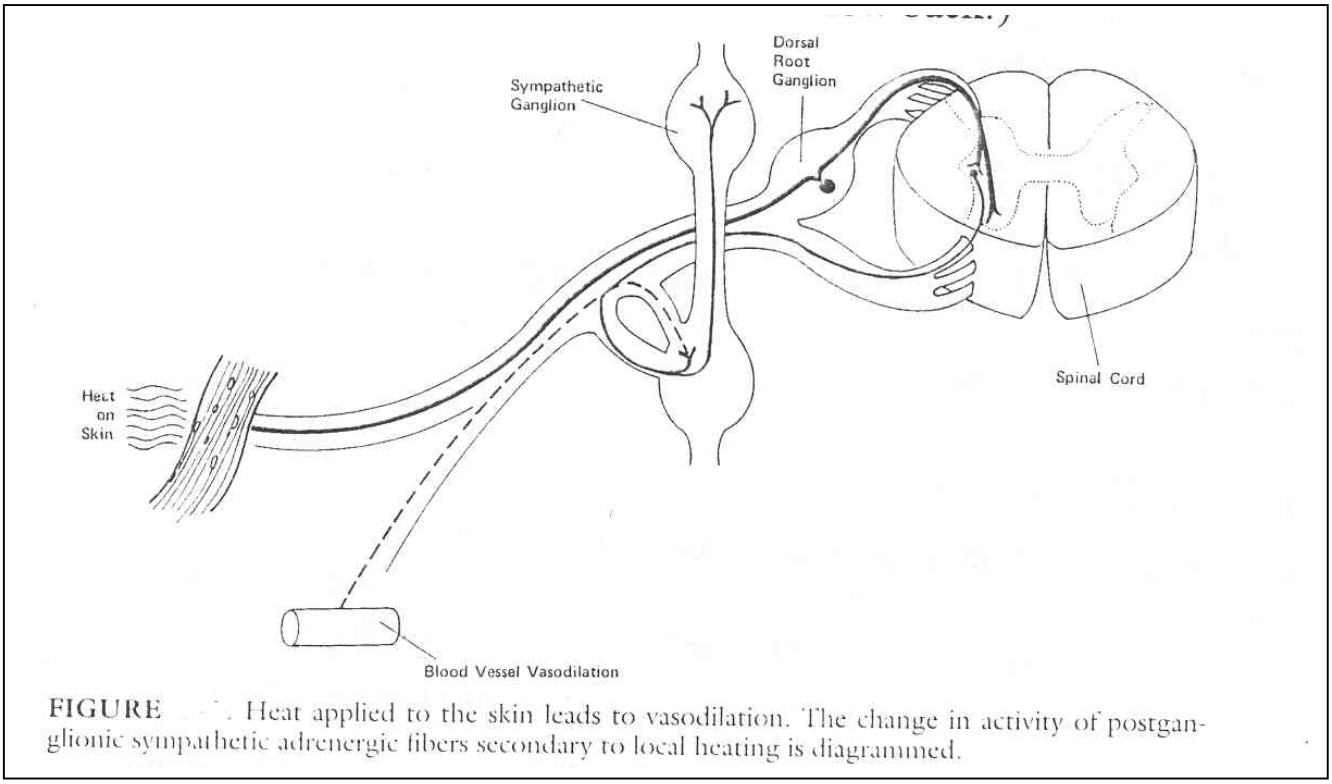


FIGURE . Heat applied to the skin leads to vasodilation. The change in activity of postganglionic sympathetic adrenergic fibers secondary to local heating is diagrammed.

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	
Advantages: ↓ pain ↑ tissue extensibility ↓ stiffness	*Disadvantages:* May cause ↑ swelling	*Advantages:* May prevent further swelling ↓ pain	*Disadvantages:* ↑ 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.