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:

\[ D = \text{area} \times k \times (T_1 - T_2) / \text{thickness of tissue} \]

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 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 generalised 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 ↓ 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 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 1-2 cm will require a longer duration of exposure (15-30 minutes and will result in smaller temp. ↑ )
- at depth 3 cm ➔ 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: O₂ uptake will ↑ and more nutrients will be available to promote healing
  ➔ the bad: tissue will burn >45-50°C 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 ➔ 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!)

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 ↑ inflamma. 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](image)

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.

2) Chesterton et al.
Skin temperature response to cryotherapy.

3) Jutte et al.
The relationship between intramuscular temperature, skin temperature and adipose
during cryotherapy and rewarming.

4) Thermotherapy for treating rheumatoid arthritis