Effects of Temperature on Neuromuscular Function

Jon Marsden
School of Health Professions
University of Plymouth
Effects in Health
Effects on Nerve

Stimulate Median Nerve
Record from digital nerves

Wrist Stimulation

Elbow Stimulation

Cooling

↓ Conduction Velocity

↑ Amplitude

Bolton et al JNNP 1981 44 407
Effects on Nerve

- Cooling
  - Impairs Na\(^+\)-K\(^+\) ATPase activity
  - Extra-axonal accumulation of K\(^+\)
  - Loss of Pump Current
  - \(\uparrow\)Na\(^+\) Channel opening time

Nerve becomes depolarised

http://kvhs.nbed.nb.ca/gallant/biology/action_potential_generation.html
Effects on Muscle Contraction

**Neuromuscular Transmission**
- More robust
  - ↑ Ach activated channel opening time
  - ↓ Ach hydrolysis rate

**Muscle fibers**
- Slow ATP-ase dependent
- Cross bridge formation

- ↓ Force
- ↓ Rate of Force Generation

Cooling
Effects on Muscle Stiffness

Passive Stiffness

Connective Tissue

Intramuscular Proteins

Titin

Cross Bridge Attachment

Gillies and Lieber, 2011 Muscle and Nerve 44 318-331

http://en.wikipedia.org/wiki/Titin
Effects on Muscle Stiffness

Passive Stiffness

Cross Bridge Attachments

Body Temperature

Post Cooling

Thixotropy
Increase in movement post perturbation

Perturbation

Similar Stiffness prior perturbation

Less reduction in stiffness after perturbation

Lakie et al, 1986 JNNP 49 69-76
Effects on Muscle Stiffness

Thermal Stability of Connective Tissue

Passive Stiffness

Effects of stretching

Stress-relaxation curve

Tendon held at this strain

Degree of Relaxation

Difference below 37 °C

Rigby et al, 1959
The J of General Physiology 43 265-283
Effects on Reflex Activity

Cutaneous Stimuli can affect Recruitment of higher threshold Motoneurons

↑Alpha Motor Neuron Excitability

Yona, 1997 Jap J Physiol 47:341-347
Effects on Reflex Activity

Cooling

- No Effect on H/M reflex
- Tendon Reflexes decrease
- Muscle spindle activity is decreased

- Inhibition of γ motoneurons
- Reduction in Group II Afferent Discharge

[Diagram](http://www.nature.com/sc/journal/v44/n12/fig_tab/3101928f1.html)
Effects in Neurological Disease
Effects of Pathology: Nerve
Demyelination and Uhthoff’s Phenomena

Demyelination

- ↑ Capacitance
- ↓ Resistance
- Current Leak
- Insufficient current to Open Na+ channels at Node of Ranvier
- Conduction Block

Warming

- Na+ ion channel Opens for shorter Period of time
- Less Time for summation of local currents
- ↑ Conduction block

http://www.msif.org/en/about_ms/demyelination.html
Effects of Pathology: Nerve

Cold Paresis

80% Multifocal motor Neuropathy

52% Spinal Muscular Atrophy

38% Chronic Demyelinating Polyneuropathy

Due to a worsening of focal depolarisation?
Effects of Pathology: Neuromuscular Junction

Myasthenia Gravis

Autoimmune Disease with antibodies blocking Ach Receptors at the Neuromuscular Junction

Warming makes symptoms worse
eg hot pack to neck increases ptosis

Warm

↑ Ach esterase

↓ Ach-induced depolarisation

Rutkove, 2001 Muscle and Nerve 24 867-882
Effects of Pathology: Muscle
Paramyotonia Congenita

50% of Na+ channels have a high permeability

Cool

Opens mutant Na+ channels

Membrane depolarisation

Opens all channels

Depolarisation

Weakness

Rutkove, 2001 Muscle and Nerve 24 867-882
Rehabilitation
Use of Temperature in Rehabilitation

Whole Body Cooling in MS

Improvements reported in

Walking speed
Balance
Strength
Fatigue

Mechanism(s) Unclear

No change in central motor conduction time

Often no change in core temperature

Use of Temperature in Rehabilitation

Cooling to Reduce Tremor

Essential Tremor

Cerebellar Tremor Due to MS

Lakie et al, 1994 JNNP 57 35-42

Feys et al, 2005 JNNP 76 373-376
Use of Temperature in Rehabilitation

Cooling to Reduce Spasticity

Baseline

Post Cooling

Reduction in clonus with prolonged cooling

Use of Temperature in Rehabilitation

Cooling to Reduce Spasticity

26 TBI
20mins cool pack

↓Reflex threshold (1.5° only)
=H reflex

↓Toe tapping

Reduced Stretch Reflex threshold with cooling

Effect of localised Warming and Cooling in Spastic Paraparesis and Multiple Sclerosis

Measure Before and After Cooling / Warming

Peripheral and Central nerve Conduction

Maximal Voluntary Contraction
Rate of Force generation
Passive Stiffness
Stretch Reflex Mediated Stiffness

Walking speed
Foot tap speed
Conclusion

Cooling can:

- Reduce nerve conduction velocity
- Reduce MVC and rate of force generation
  - Increase passive stiffness
  - Decreases tendon reflexes

Warming can have the opposite effect

The effects of temperature changes depends on:

- The underlying pathology
- The site of intervention
- The duration of intervention
The Research Team

Jon Marsden  
Amanda Austin  
Lisa Bunn  
Alan Hough

Other Team Members:
Simon Hubbard  
Ian Bennett  
Susie Wolstenholme

Awarding Body
Chartered Society of Physiotherapy