Muscle oxygenation studies in athletes

Chris Cooper
Near-Infrared Spectroscopy: an Established Clinical Monitoring Tool for the Brain?

Slide courtesy of ILIAS TACHTSIDIS
Outline of talk

1. Introduction to tissue optics

2. Use of near infrared spectroscopy (NIRS) to measure oxygenation in the muscle in vivo

3. Two examples from sports physiology
Near infrared spectroscopy

Arterial Hb saturation

\[
\frac{[\text{HbO}_2]}{[\text{Hb}] + [\text{HbO}_2]} \times 100
\]

Tells you how well lungs oxygenate blood
Haemoglobin (blood)

\[ \text{Hb} + \text{O}_2 \quad = \quad \text{HbO}_2 \]
Basis of NIRS - light gets into tissue

![Graph showing absorption coefficients for different wavelengths with peaks at Haemoglobin and Water]
Basic optical set up to detect multiple wavelengths of light simultaneously

Laser/
LED
(2-4 wavelengths)

Detector
What does NIRS measure?

Scattered/absorbed

Detected

Scattered detected

Absorbed

Scattered not detected

Tissue

Detector
Simple “continuous wave NIRS”

- Difference spectroscopy (tissue baseline)
- Assume scattering does not change
- Measure optical pathlength (cm)
- Beer-Lambert Law $\Delta A = \varepsilon \Delta c . l.$

Measure (in ms time scale):

$\Delta$ HHb $\mu M$

$\Delta$ HbO$_2$ $\mu M$

$\Delta$ total Hb (HHb + HbO$_2$) $\mu M$

$\Delta$ oxygenation (HbO$_2$ - HHb) $\mu M$

(myoglobin is elephant in the room)
Spatially resolved spectroscopy

Absolute Hemo(myo)globin  % Saturation in tissue:

\[
\frac{\text{HbO}_2}{\text{Hb} + \text{HbO}_2} \times 100
\]
Where does the light go? Muscle

Image courtesy of Hutchinson Technology Inc.
Where does the light go? Brain
Measuring brain fatigue with NIRS in exhaustive exercise

Dave Parry             Dominick Micklewright
What happens to the muscle when it is activated?
Muscle activation deoxygenates tissue
ΔO₂Hb

ΔHHb

ΔtHb

Time (s)

0 2 10 18 35 45

Rest 3-s contraction #1 3-s contraction #3 3-s contraction #5 15-s contraction Recovery

Taka Hamaoka Japan

0.025 (mM)

-0.035
Effect of warm-up on muscle oxygenation and metabolism in supramaximal cycling

Anna Wittekind, Chris Cooper, Caroline Angus, Clare Elwell*, Terence Leung*, Ralph Beneke
Conclusions

• Higher intensity warm-up
  – which raised $BLC_{pre}$
  – faster oxygen utilisation

• However
  – reduced power in 30 s all-out cycling
  – reduction in glycolytic energy
  – not compensated for by anaerobic alactic or aerobic metabolism.

• Caution! warm-up eliciting improved oxygen utilisation may not compensate for reduced anaerobic glycolytic energy
PORTABLE MEASUREMENTS ON MUSCLE: TAKE NIRS INTO REAL SPORT

Britton Chance
University of Pennsylvania

1993: RUNMAN™
PORTABLE MEASUREMENTS ON MUSCLE: TAKE NIRS INTO REAL SPORT
Toshihito Katsumura, MD, PhD Dept. of Sports Medicine for Health Promotion Tokyo Medical University
The PortaMon (Artinis Systems)
portable wireless NIRS system device

\[
\text{TSI (\%)} = \frac{\text{HbO}_2}{\text{Hb} + \text{HbO}_2} \times 100
\]

Tissue Saturation Index (TSI): multiple sensors at different distances allow quantitative measure of tissue oxygen saturation to be derived.

Emitters (light at wavelengths 850nm and 760nm): 30, 35, 40mm from detector.

Detector

82mm

50mm
Near Infrared Spectroscopy Measurements in Elite Short-track Speed Skaters During On-ice Race Simulation

Presented by: Catherine Hesford
Supervisor: Professor Chris Cooper
In Summary....

• First study of the asymmetry of oxygenation in short-track speed skating

• Clear differences between the right and left leg during 500m race simulation

• Differences are evident over a single lap, and also cumulatively over the course of a whole race simulation

• Potential performance implications of such a finding?

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