

R. Luke Harris

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Innovation and Development Commons

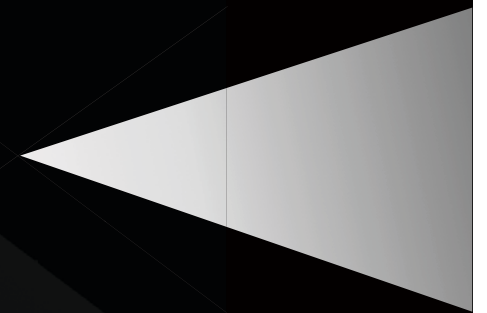
Brown Bag Seminar



April 28, 2016

**BRAIN AND MUSCLE CIRCULATION AND METABOLISM:
FOCUS ON NON-INVASIVE MONITORING FOR
REHABILITATION AND EXERCISE RESEARCH**

What is NIRS?





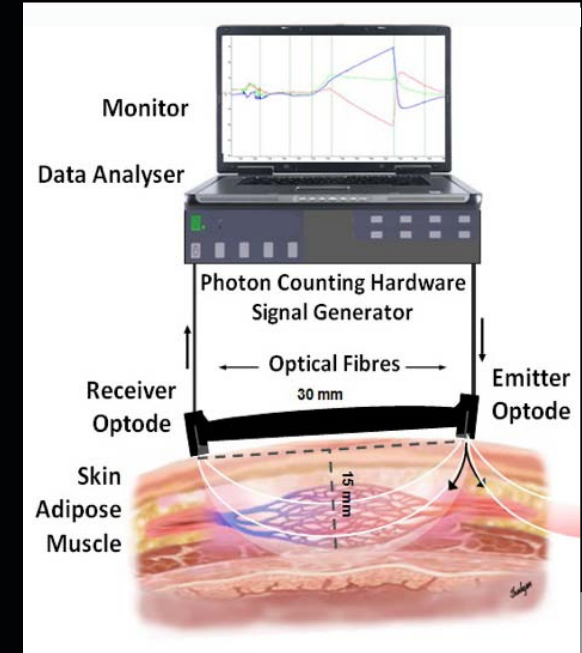
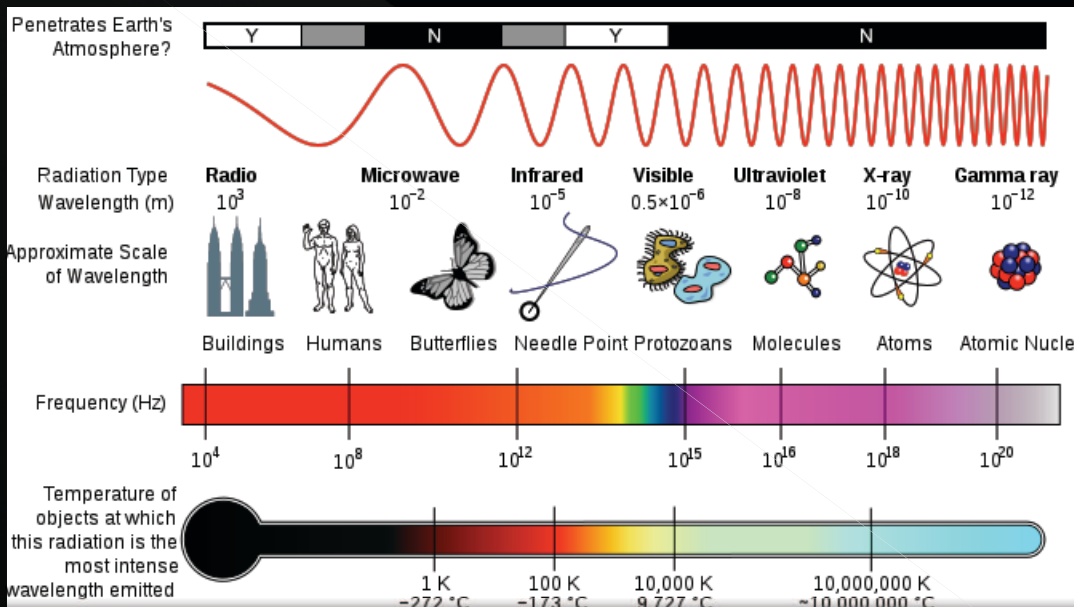
- Biological tissues including brain, muscle, and—to a lesser extent—bone are relatively transparent to photons in the near infrared (NIR) spectrum.

Girl With a Candle
Godfried Cornelisz, ~1670-1675



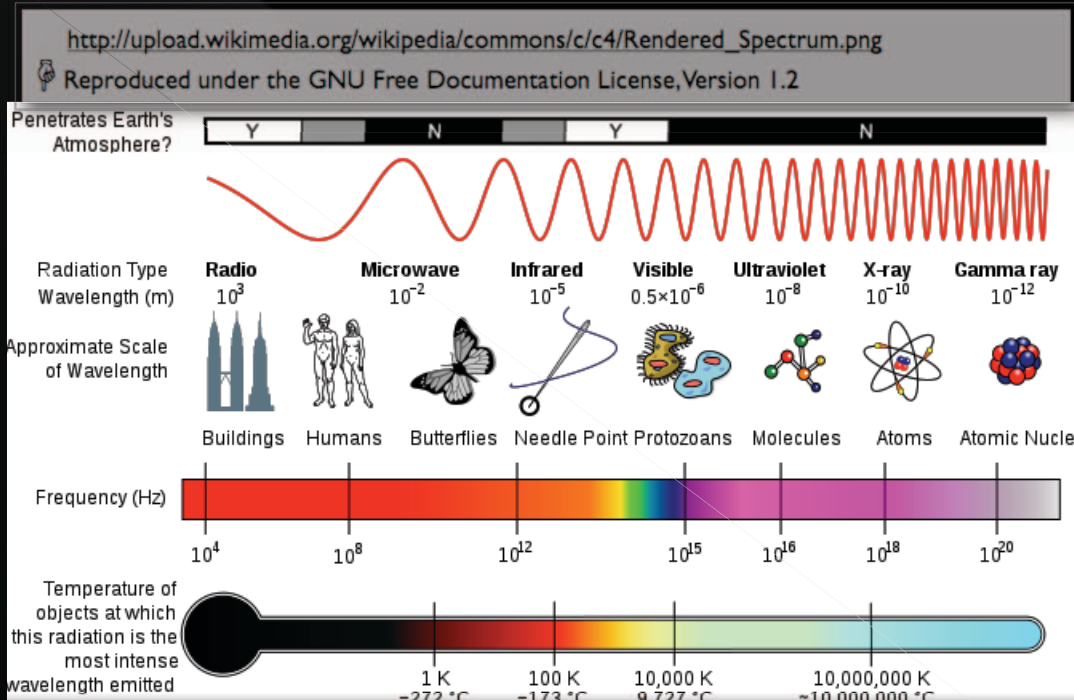
NIRS is validated for real-time monitoring of brain and muscle oxygenation and haemodynamics.

O'Brien et al. COMOC, Edinburgh UK, 2010.

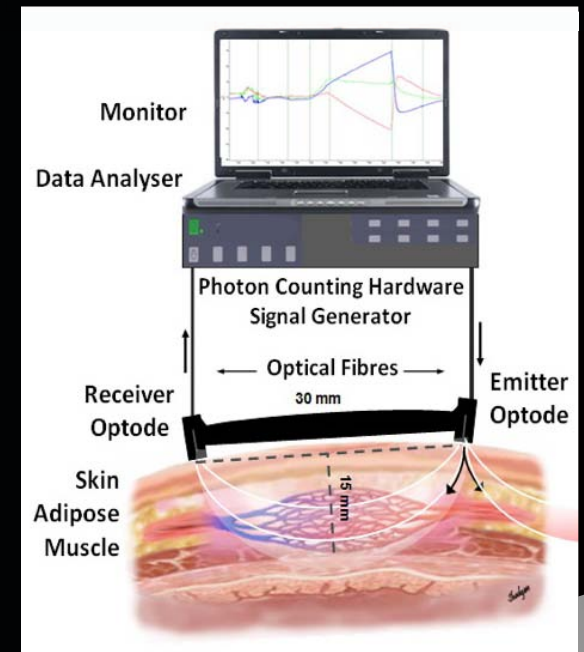


- Brain and muscle are relatively transparent to photons in the near-infrared (NIR) spectrum and, conveniently, the photons also pass through skin, subcutaneous fat, and bone tissue.

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O'Brien et al. COMOC, Edinburgh UK, 2010.



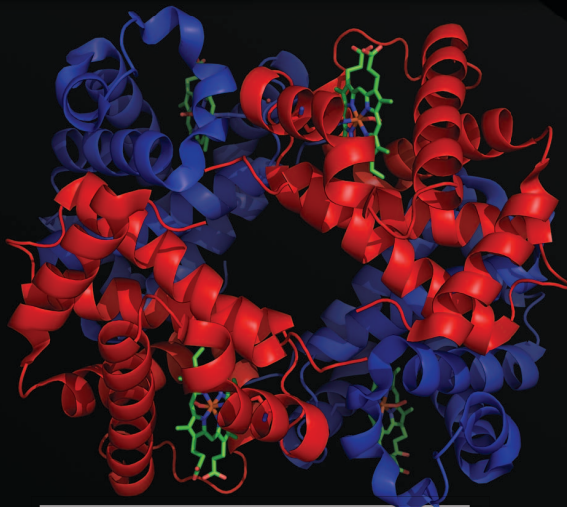
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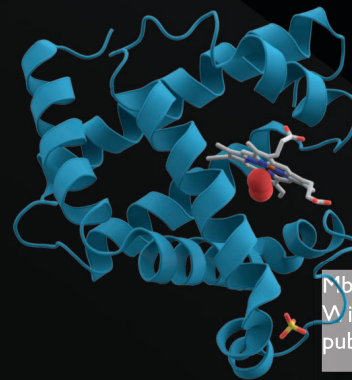
- Signal recording depends on oxygen-dependent hemoglobin (Hb) and myoglobin (Mb) photon absorption changes in, respectively, capillaries and muscle.*

*Shadgan et al. *Spectroscopy*, 2009.

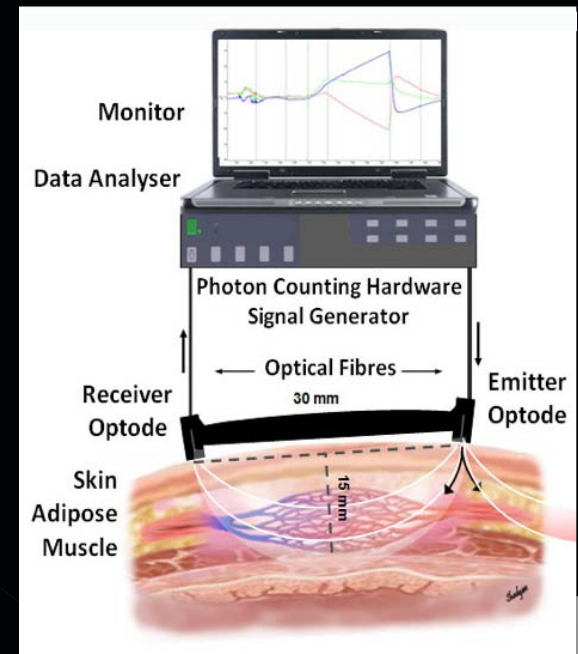
O'Brien et al. COMOC, Edinburgh UK, 2010.



Hb image obtained from Wikimedia and reproduced under Creative Commons license. Created by user Zephyris.



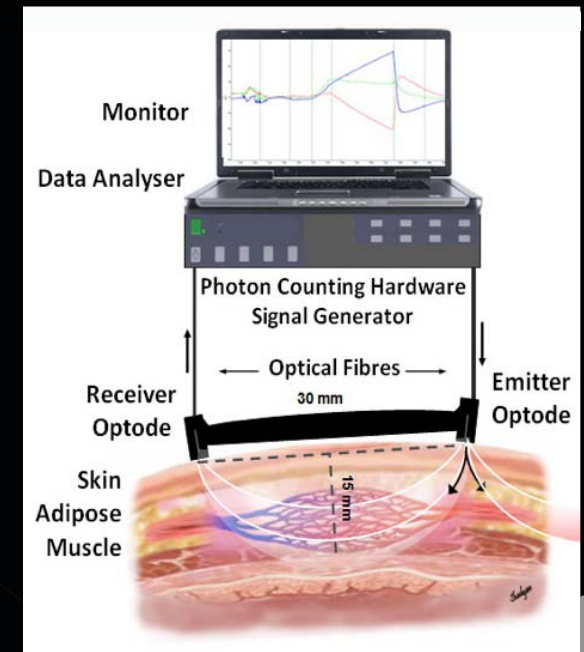
Mb image obtained from Wikimedia. Released into the public domain by user AzaToth.



NIRS is validated for real-time monitoring of brain and muscle oxygenation and haemodynamics.

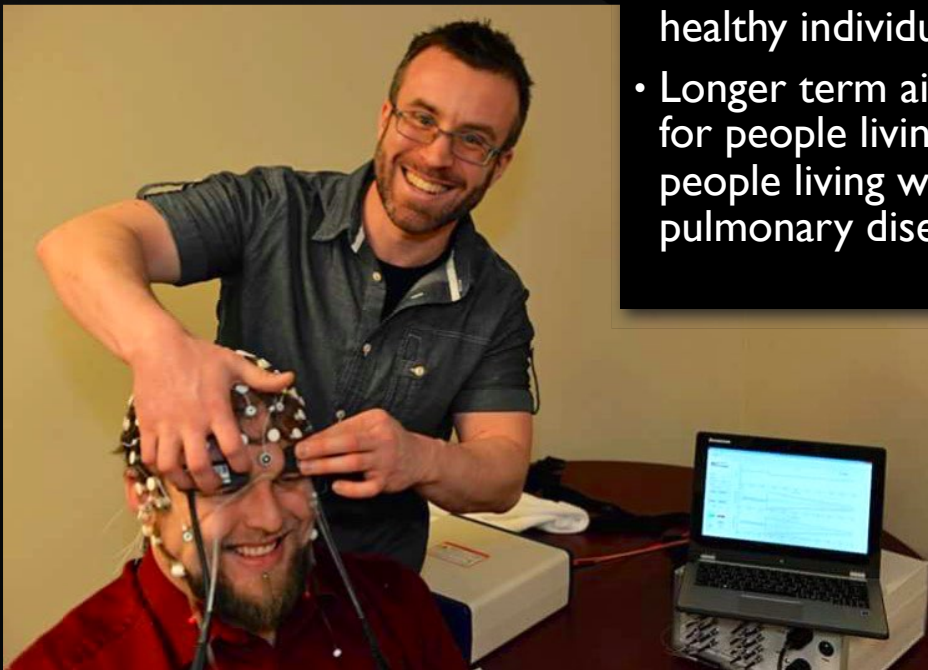
- Tissue penetration depth is $\sim\frac{1}{2}$ the distance between the emitter and receiver optodes
- Total penetration depths of up to 5 cm are sometimes used clinically (e.g. for abdominal tissues in the perinatal setting), but for practical purposes only ~ 2 cm into muscle and only ~ 3 -5 mm into muscle are realistic.
 - Mathematically, this is because of the *banana-shaped curve* followed by those photons that arrive at the receiver optode. Simply, the radius, or penetration depth, is equivalent to half the diameter.
 - Not all photons emitted follow this path. Many lose energy to absorption and scattering.

O'Brien et al. COMOC, Edinburgh UK, 2010.



Northern BC Near-Infrared Spectroscopy Lab

- Our primary goals are to promote improved brain function and respiratory function throughout the healthspan.
- Current projects focus on investigating fundamental functions of the brain and the respiratory system in relatively young and healthy individuals.
- Longer term aims are to develop novel rehabilitation opportunities for people living with acquired brain injuries like stroke, or for people living with respiratory diseases like chronic obstructive pulmonary disease (COPD).

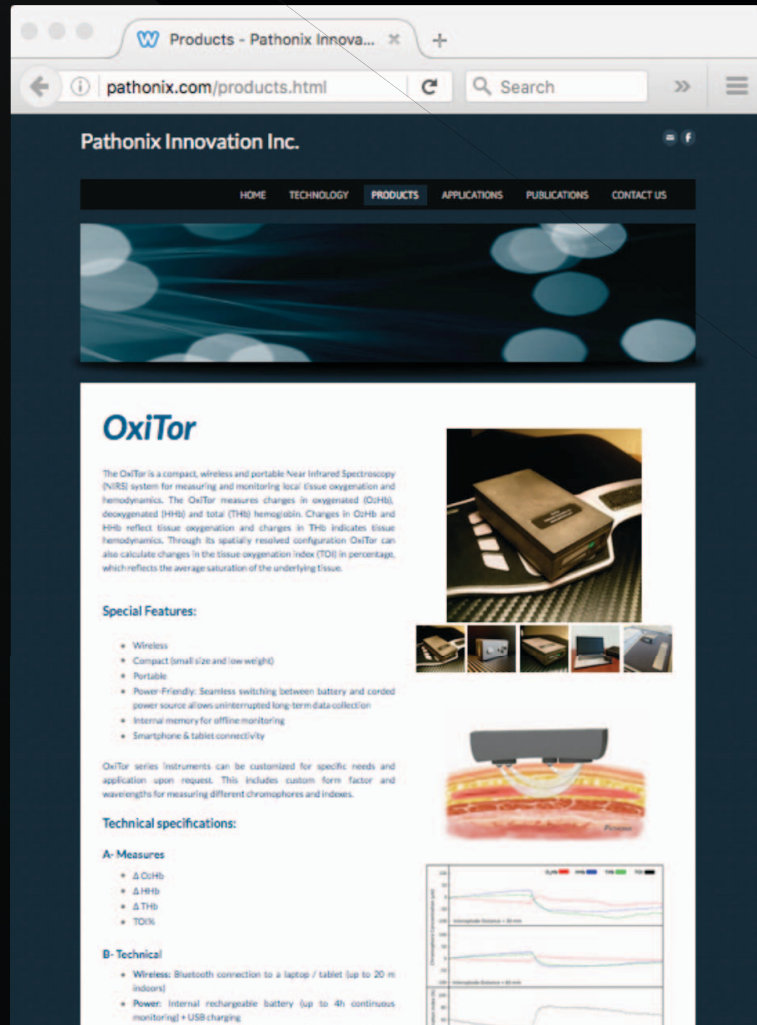


Northern BC Near-Infrared Spectroscopy Lab

- Funded by infrastructure support from
 - Canada Foundation for Innovation and the British Columbia Knowledge Development Fund (matching funds)
 - UNBC College of Arts, Social and Health Sciences
 - UBC Northern Medical Program
 - Generous discounts from our suppliers



Northern BC Near-Infrared Spectroscopy Lab

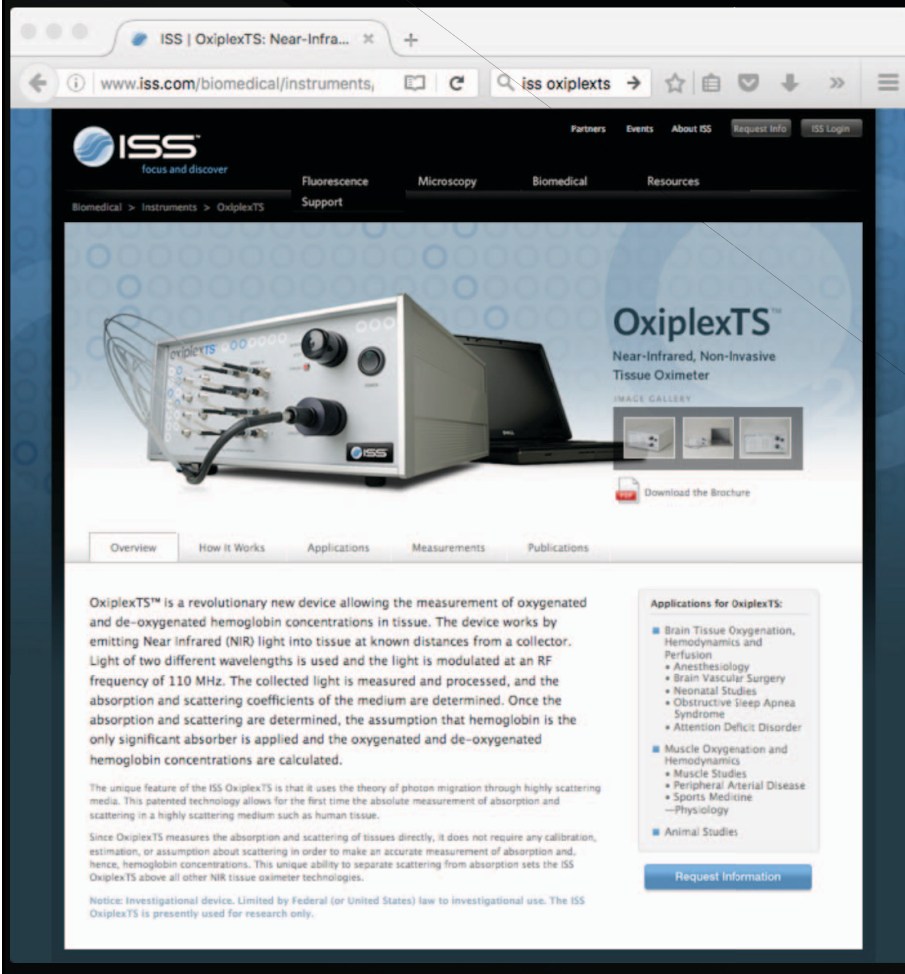


The screenshot shows a web browser displaying the Pathonix Innovation Inc. website. The page is titled "OxiTor" and features a navigation menu with "HOME", "TECHNOLOGY", "PRODUCTS", "APPLICATIONS", "PUBLICATIONS", and "CONTACT US". The main content area includes a description of the OxiTor device, its special features, technical specifications, and a diagram of the device's application on a human head. The description states: "The OxiTor is a compact, wireless and portable Near Infrared Spectroscopy (NIRS) system for measuring and monitoring local tissue oxygenation and hemodynamics. The OxiTor measures changes in oxygenated (OxHb), deoxygenated (HHb) and total (THb) hemoglobin. Changes in OxHb and HHb reflect tissue oxygenation and changes in THb indicates tissue hemodynamics. Through its spatially resolved configuration OxiTor can also calculate changes in the tissue oxygenation index (TOI) in percentage, which reflects the average saturation of the underlying tissue." The special features listed are: Wireless, Compact (small size and low weight), Portable, Power-Friendly (Seamless switching between battery and corded power source allows uninterrupted long-term data collection), Internal memory for offline monitoring, and Smartphone & tablet connectivity. The technical specifications are divided into A-Measures (ΔOxHb, ΔHHb, ΔTHb, TOI%) and B-Technical (Wireless: Bluetooth connection to a laptop / tablet (up to 20 m indoors), Power: Internal rechargeable battery (up to 4h continuous monitoring) + USB charging). A diagram shows the OxiTor device on a human head, and a graph displays the measured data for ΔOxHb, ΔHHb, ΔTHb, and TOI% over time.

• Our equipment

- Four portable, wireless OxiTor M2 NIRS instruments supplied by Pathonix Innovation, Inc., a Vancouver startup who are the only Canadian designers/builders/vendors of wireless NIRS instruments.
- Used exclusively for muscle measurements.
- Primary limitation is that it is a “spatially resolved” NIRS configuration that only permits measuring relative changes from baseline.

Northern BC Near-Infrared Spectroscopy Lab

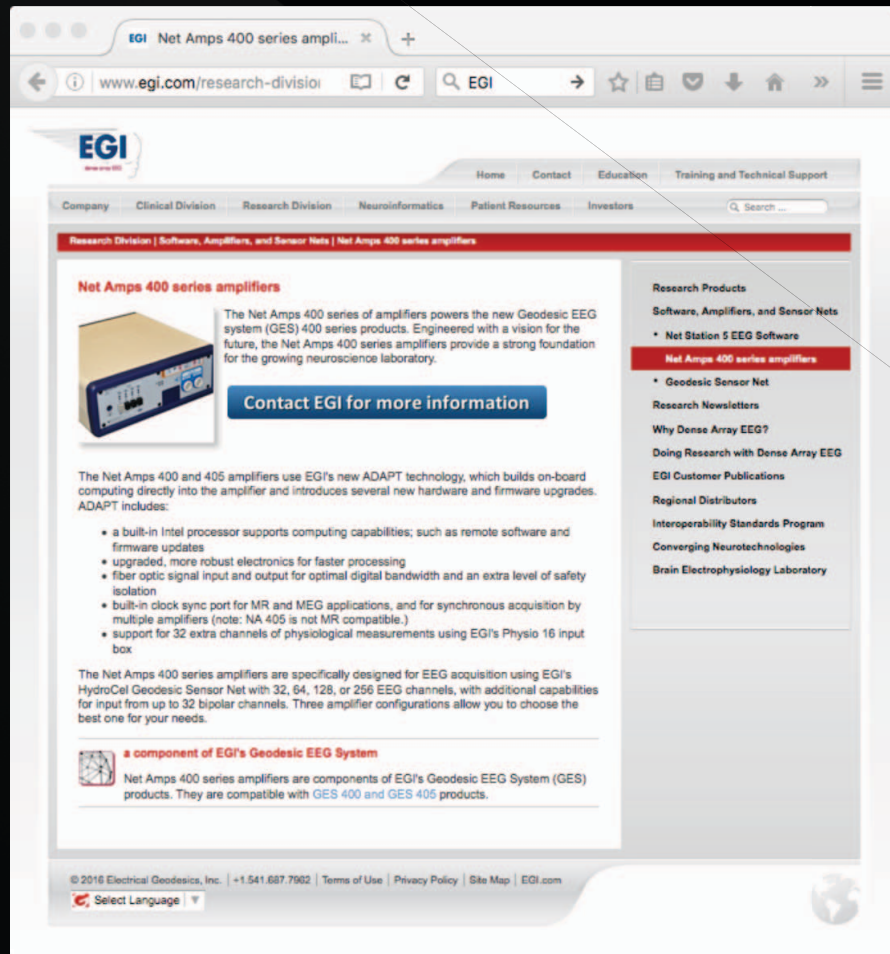


The screenshot shows the ISS OxiplexTS product page. The browser address bar displays 'www.iss.com/biomedical/instruments'. The page features the ISS logo with the tagline 'focus and discover'. Navigation tabs include 'Fluorescence', 'Microscopy', 'Biomedical', and 'Resources'. The main content area shows a photograph of the OxiplexTS device, a white rectangular unit with various ports and a control knob. Text on the page describes the device as a 'Near-Infrared, Non-Invasive Tissue Oximeter'. A 'Download the Brochure' button is visible. Below the main image, there are sections for 'Overview', 'How It Works', 'Applications', 'Measurements', and 'Publications'. The 'Applications' section lists various medical and research uses, including brain tissue oxygenation, muscle oxygenation, and animal studies. A 'Request Information' button is located at the bottom of the page.

• Our equipment

- A 2-channel, frequency-domain OxiplexTS instrument from ISS, Inc. (Champaign, IL)
- Can be used for brain and muscle measurements.
- Considered a “gold standard” NIRS instrument as the patented frequency-domain configuration permits absolute measurements.
- However, it is not portable, and yields values that are subject to relatively low signal-to-noise ratio, therefore requiring heavy filtering prior to analysis.

Northern BC Near-Infrared Spectroscopy Lab



The screenshot shows the EGI website's product page for Net Amps 400 series amplifiers. The page features a navigation menu at the top, a search bar, and a main content area with a product image, a 'Contact EGI for more information' button, and detailed text about the ADAPT technology and specifications. A sidebar on the right lists various research products and services.

Net Amps 400 series amplifiers

The Net Amps 400 series of amplifiers powers the new Geodesic EEG system (GES) 400 series products. Engineered with a vision for the future, the Net Amps 400 series amplifiers provide a strong foundation for the growing neuroscience laboratory.

[Contact EGI for more information](#)

The Net Amps 400 and 405 amplifiers use EGI's new ADAPT technology, which builds on-board computing directly into the amplifier and introduces several new hardware and firmware upgrades. ADAPT includes:

- a built-in Intel processor supports computing capabilities; such as remote software and firmware updates
- upgraded, more robust electronics for faster processing
- fiber optic signal input and output for optimal digital bandwidth and an extra level of safety isolation
- built-in clock sync port for MR and MEG applications, and for synchronous acquisition by multiple amplifiers (note: NA 405 is not MR compatible.)
- support for 32 extra channels of physiological measurements using EGI's Physio 16 input box

The Net Amps 400 series amplifiers are specifically designed for EEG acquisition using EGI's HydroCel Geodesic Sensor Net with 32, 64, 128, or 256 EEG channels, with additional capabilities for input from up to 32 bipolar channels. Three amplifier configurations allow you to choose the best one for your needs.

a component of EGI's Geodesic EEG System

Net Amps 400 series amplifiers are components of EGI's Geodesic EEG System (GES) products. They are compatible with GES 400 and GES 405 products.

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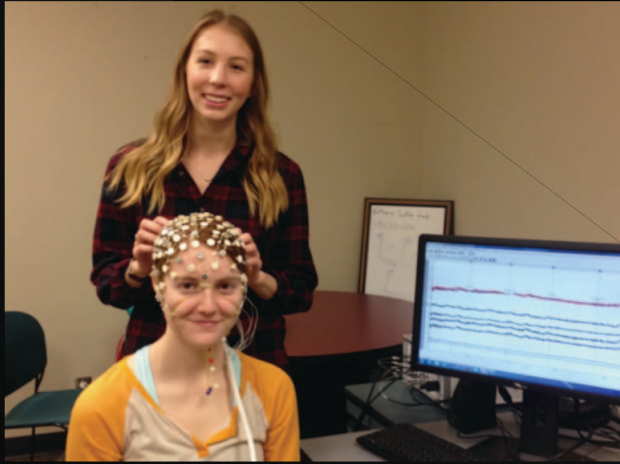
Select Language

• Our equipment

- An Electrical Geodesics, Inc. Net Amps 400 system with 32-channel EEG (electroencephalography), and a 16-channel PNS recording system for EMG, ECG, pulse-ox, etc.



Northern BC Near-Infrared Spectroscopy Lab



- This combination of instruments makes it possible for us to perform simultaneous non-invasive recording of metabolic and electrical activity from the brain and from four muscles, along with ECG and a few other peripheral parameters, during a relatively stationary rehabilitation exercise task.
- As yet we have not been so ambitious...


Acute Hyperglycaemia Impairs Prefrontal Blood Flow and Oxygenation During Declarative Memory Tasks

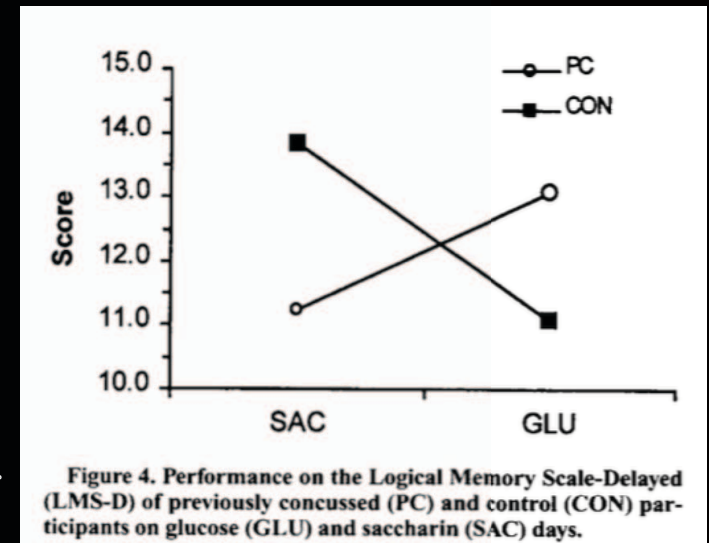
Duffels B ¹, Bell L ¹, Reimer A ², Pettersen J ³, Siakaluk P ¹, Harris RL ²
UNBC ¹Psychology Department and ²School of Health Sciences, ³UBC
Northern Medical Program
Special thanks to J Jantzen and K Takaoka



Acute Hyperglycaemia Impairs Prefrontal Blood Flow and Oxygenation During Declarative Memory Tasks

Duffels B¹, Bell L¹, Reimer A², Pettersen JA³, Siakaluk P¹, Harris RL²
UNBC¹ Psychology Department and ²School of Health Sciences,
³UBC Northern Medical Program

Pettersen & Skelton *Psychobiology*, 2000 



- Using standardized behavioural tasks, Pettersen & Skelton (2000) demonstrated that ingested glucose hinders long-term declarative memory in control subjects.

Acute Hyperglycaemia Impairs Prefrontal Blood Flow and Oxygenation During Declarative Memory Tasks

Rupp et al. *Oxygen Transport to Tissue XXXV*, 2013 

- By monitoring total cerebral blood flow concurrently with blood-oxygen saturation using NIRS, it is possible to distinguish between aerobic and glucose-driven operations during functional tasks.

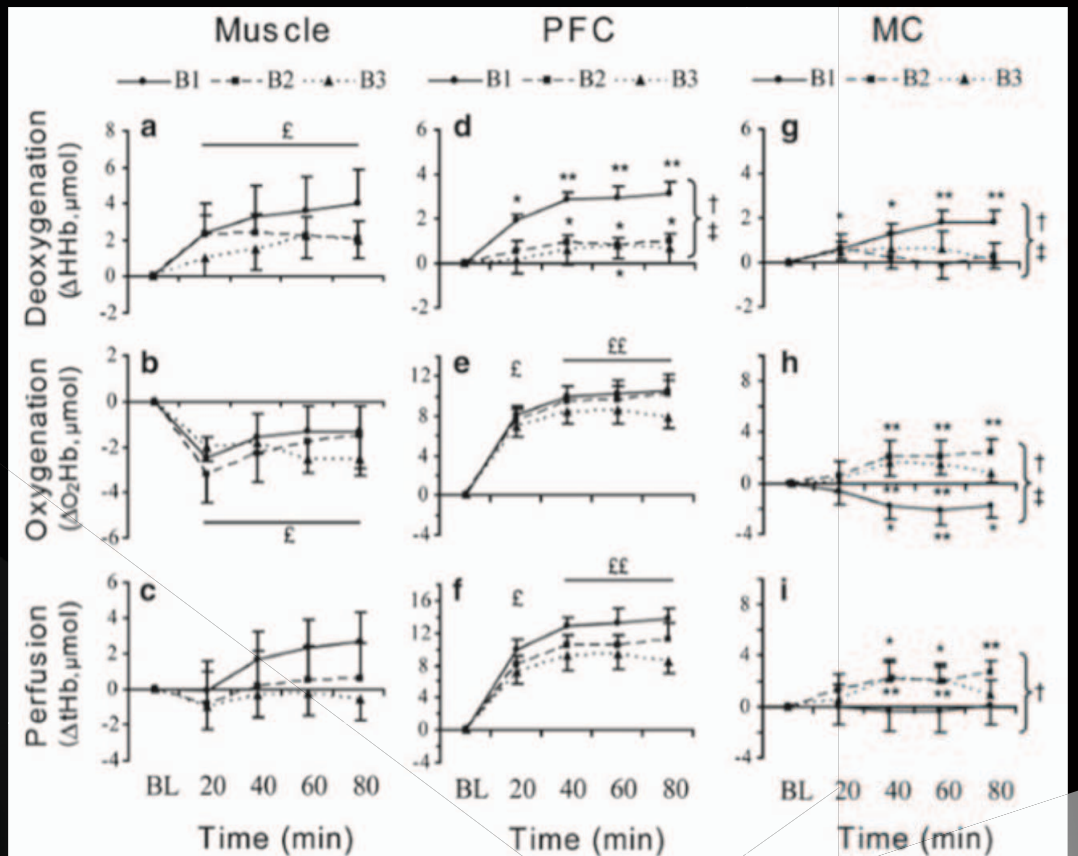

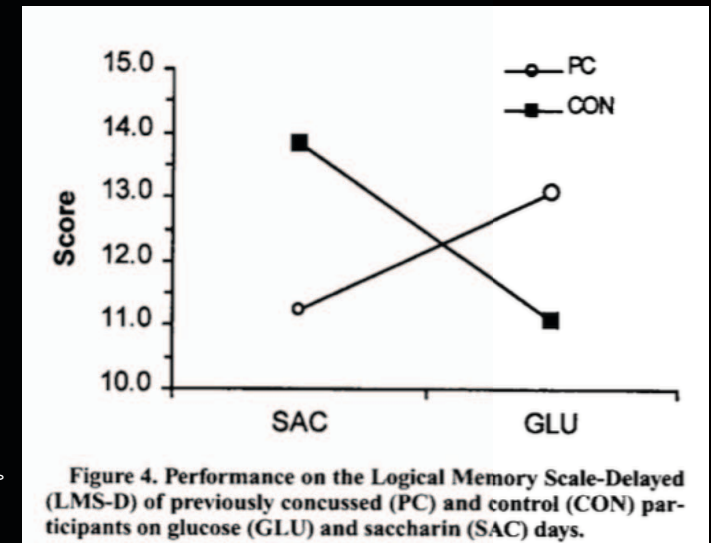


Fig. 21.1 Changes in oxy-([HbO₂]), deoxy-([HHb]), and total-hemoglobin ([THb]) from BL during each of the first (B1), second (B2), and third (B3) exercise bouts. Results are shown for the *vastus lateralis* muscle (left panels), for the prefrontal cortex (PFC, middle panels), and for the motor cortex (MC, right panels). Values are mean ± SE. Significant main effect of time: £ versus BL, ££ versus +20 min. Significant main effect of bout: † B2 versus B1, ‡ B3 versus B1. Significant main interaction effect: * versus BL, ** versus +20 min

Acute Hyperglycaemia Impairs Prefrontal Blood Flow and Oxygenation During Declarative Memory Tasks

Pettersen & Skelton *Psychobiology*, 2000 



- We aimed to elaborate upon Pettersen's & Skelton's (2000) memory data by using NIRS to monitor hemodynamics and oxygenation during a battery of memory tests.

Acute Hyperglycaemia Impairs Prefrontal Blood Flow and Oxygenation During Declarative Memory Tasks

- In addition, we incorporated a semantic categorization task (SCT) to examine associated brain hemodynamics and oxygenation during language processing, as there are only three publications examining SCT performance with NIRS.
- Developed by Paul Siakaluk (2006), the SCT requires participants to distinguish between words that have high versus low body-object interactivity.

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BOI means “how easily words’ referents can be interacted with physically. Taking an example provided by Hargreaves and colleagues (2012), a word high in BOI could be ‘belt,’ while a word low in BOI could be ‘sun,’ based on how easy it is for an individual to interact with these words’ referents. In examining response times to [high BOI] words amongst other more abstract words... it was found that high BOI words elicited significantly faster responses compared to low BOI words in... linguistic tasks.”

Bell L, 2016 Undergraduate Honours Thesis

Acute Hyperglycaemia Impairs Prefrontal Blood Flow and Oxygenation During Declarative Memory Tasks

- We have removed our methods and data from this presentation since they are preliminary findings that have not yet been published.

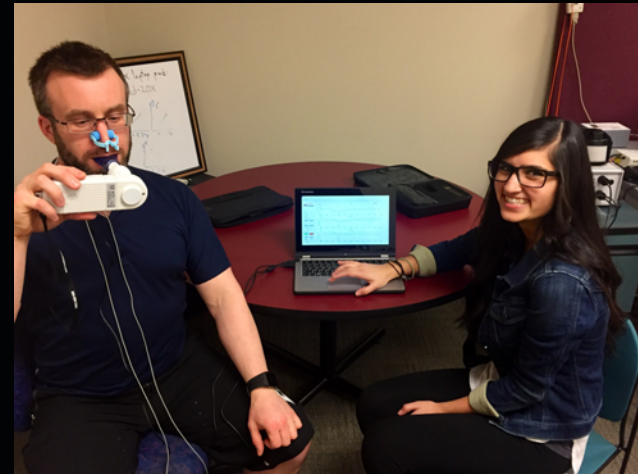
Respiratory Muscle Adaptations to Detraining in Competitive Soccer Players

Grob T, Schwab T, Sandhu K, Harris RL

UNBC School of Health Sciences

Special thanks to M Webber


Extra-Special thanks to the UNBC Men's Timberwolves Soccer Team!

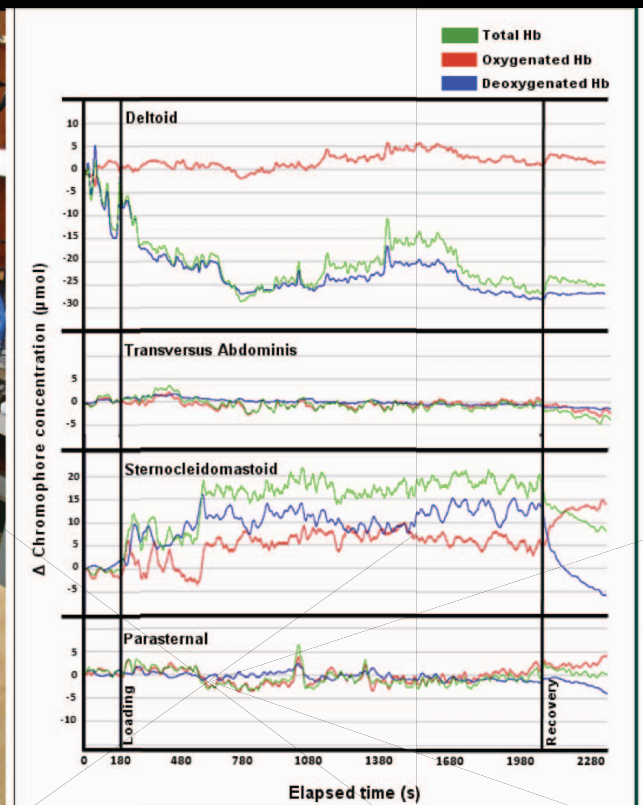
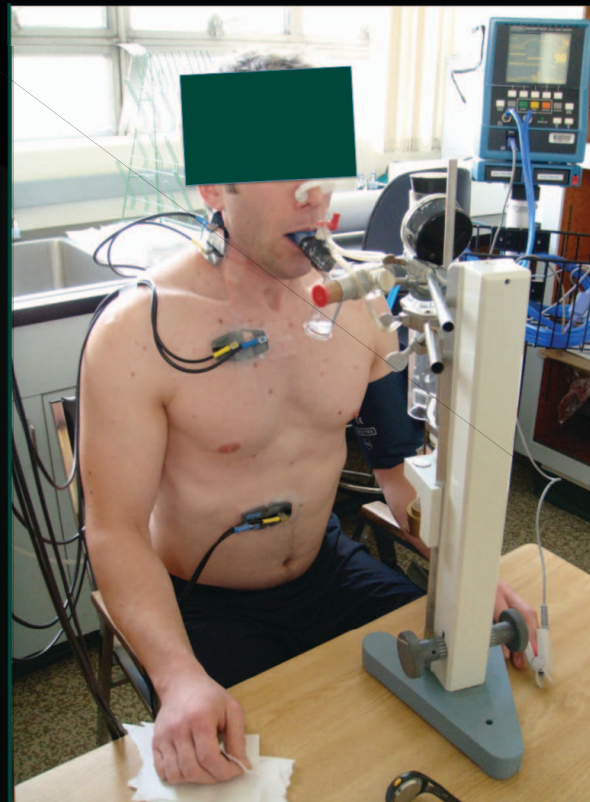


Respiratory Muscle Adaptations to Detraining in Competitive Soccer Players

Grob T, Schwab T, Sandhu K, Harris RL
UNBC School of Health Sciences

- Several groups have shown important effects of respiratory exercise on hemodynamics (e.g. blood flow) and oxygenation on muscles of the limbs and respiratory system.
- Some of our earliest pilot work at UNBC demonstrated that we should be able to measure very robust changes in respiratory muscle hemodynamics during basic respiratory function tests.

Fowler, Tippett, and Harris, 2013 



Respiratory Muscle Adaptations to Detraining in Competitive Soccer Players

- The purpose of this study was to investigate the metabolic adaptations of the respiratory muscles (ventilatory pump muscles) to detraining in competitive, varsity-level soccer players.



Respiratory Muscle Adaptations to Detraining in Competitive Soccer Players

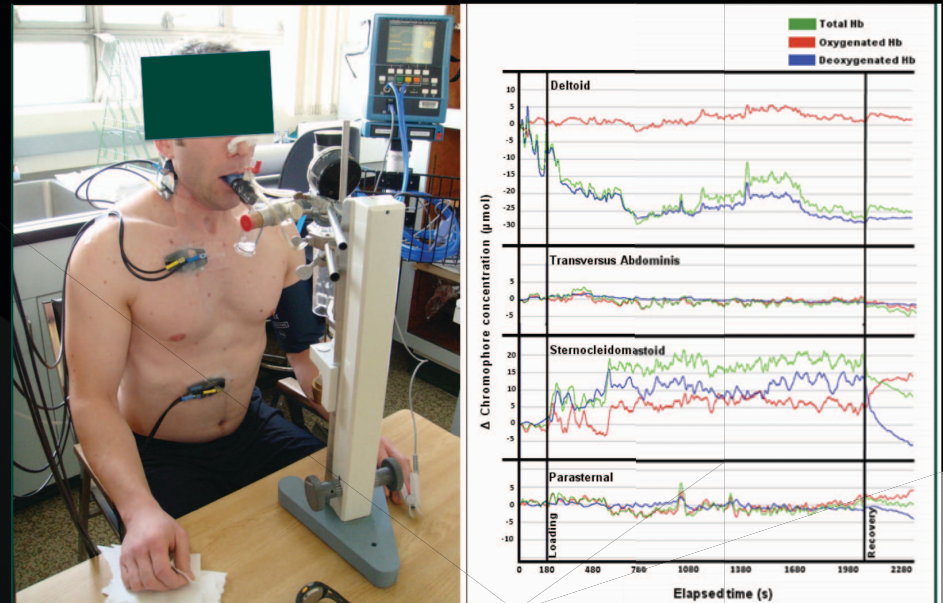
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Respiratory Muscle Adaptations to Detraining in Competitive Soccer Players

CONCLUSIONS and FUTURE DIRECTIONS

- We may be able to further enhance respiratory function and respiratory muscle performance in athletes using respiratory muscle training.
- More importantly, we have demonstrated that using low-intensity exercises and standard respiratory function tests, in people with respiratory diseases including asthma and COPD, our instrumentation is sufficiently sensitive to detect declines in lung health over periods of weeks to months.
- Our main next step in this research is to test a no-resistance respiratory training instrument in healthy participants to see if we can observe beneficial adaptations in lung health.



Thank you!

Questions?

Operating funds for this research were generously provided by

- the UNBC Office of Research (to RL Harris),
- the Northern Medical Program (to RL Harris and JA Pettersen),
- the BC Ministry of Advanced Education and the UNBC Office of Graduate Programs (to B Duffels), and
- the UNBC Centre for Teaching, Learning and Technology in collaboration with the UNBC Office of Research, through the URE award program (to K Sandhu and A Reimer).