R. Luke Harris
Associate Professor, School of Health Sciences

Innovation and Development Commons
Brown Bag Seminar

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

April 28, 2016

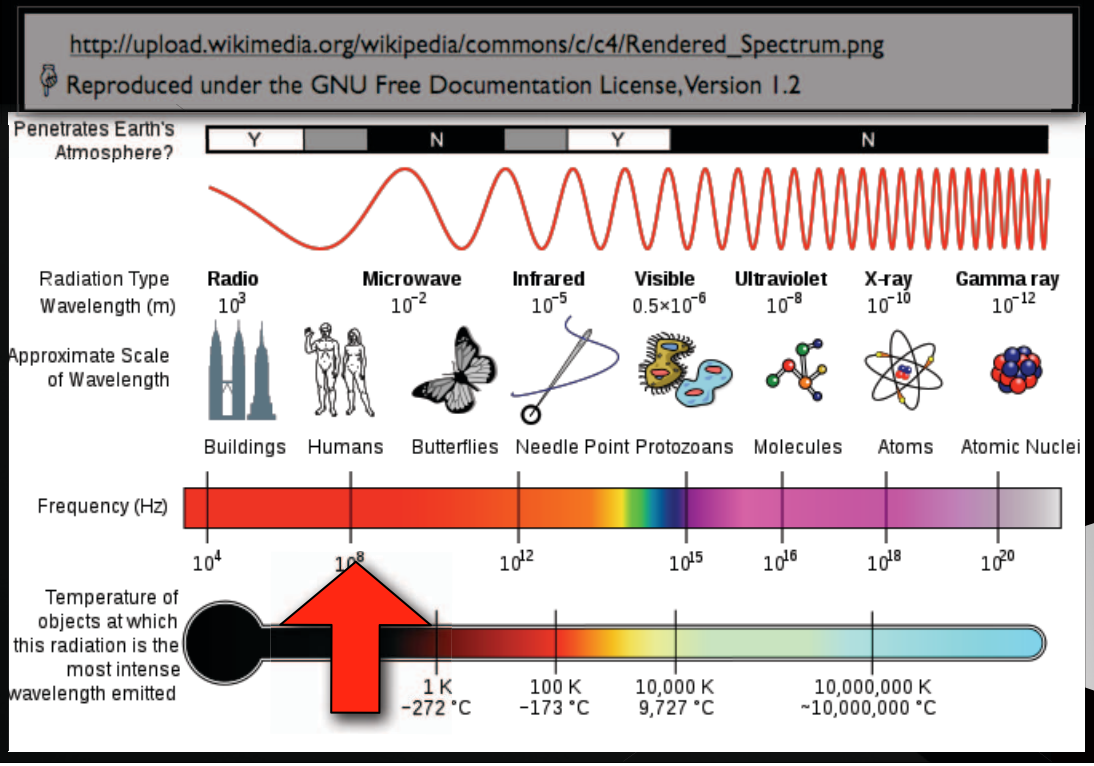
BRAIN AND MUSCLE CIRCULATION AND METABOLISM: FOCUS ON NON-INVASIVE MONITORING FOR REHABILITATION AND EXERCISE RESEARCH

What is NIRS?

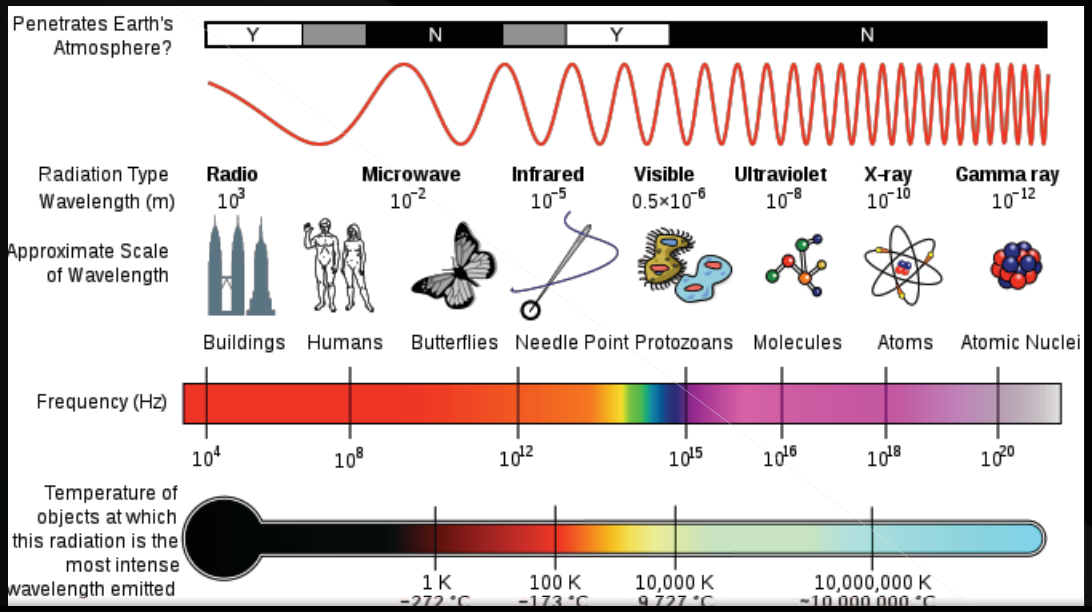
- Biological tissues including brain, muscle, and—to a lesser extent—bone are relatively transparent to photons in the near infrared (NIR) spectrum.

Girl With a Candle
Godfried Cornelisz, ~1670-1675

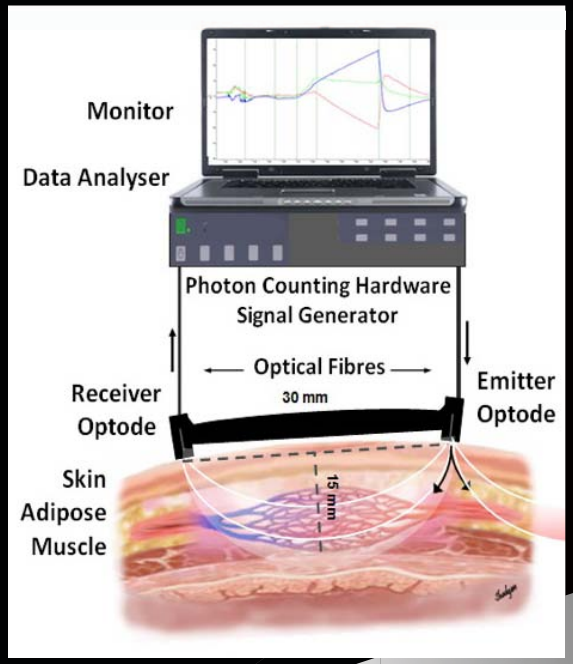
- Biological tissues including brain, muscle, and—to a lesser extent—bone are relatively transparent to photons in the near infrared (NIR) spectrum.
- Specifically, this means non-visible light with wavelengths ~650 to 1100 nm, just a bit longer than than the visible spectrum.
- NIR *spectroscopy*, or NIRS, is a tool that records changes in light observed in this wavelength range.



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.

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

http://upload.wikimedia.org/wikipedia/commons/c/c4/Rendered_Spectrum.png
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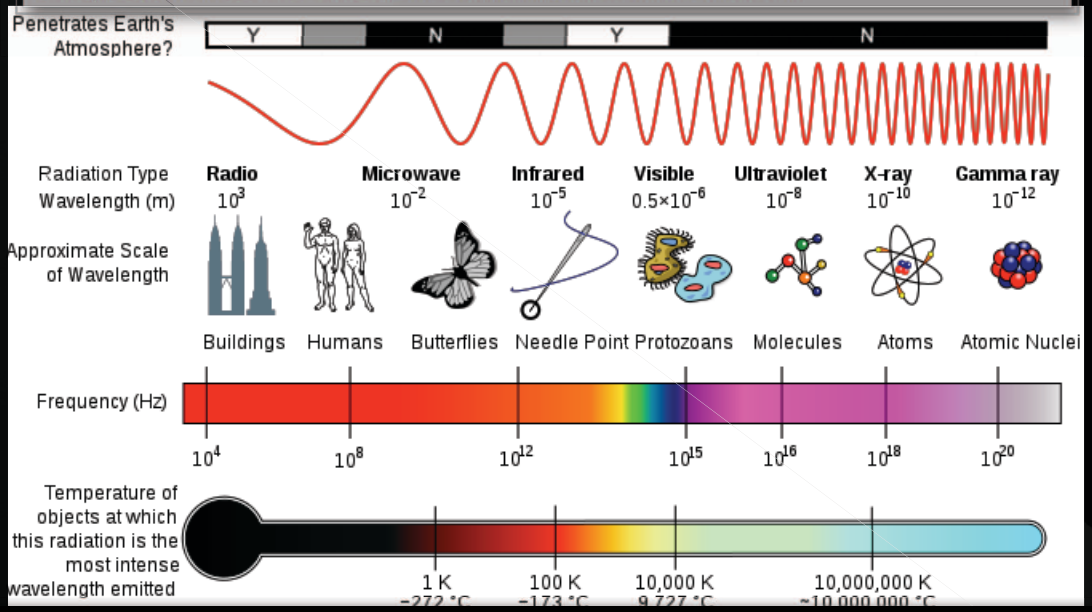

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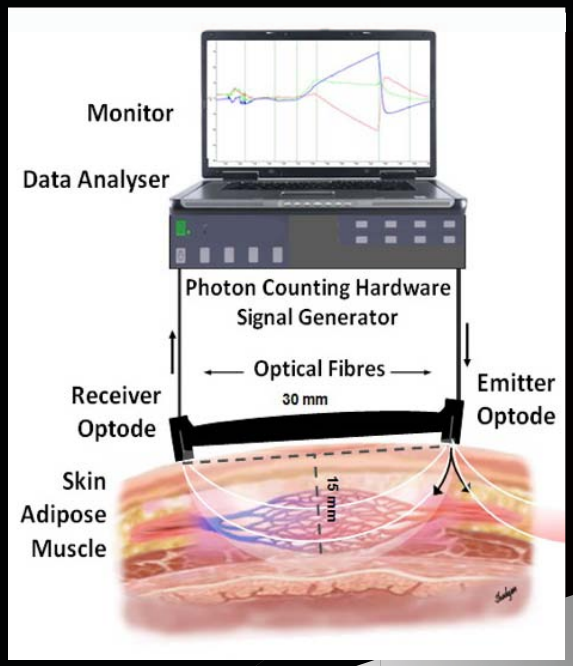

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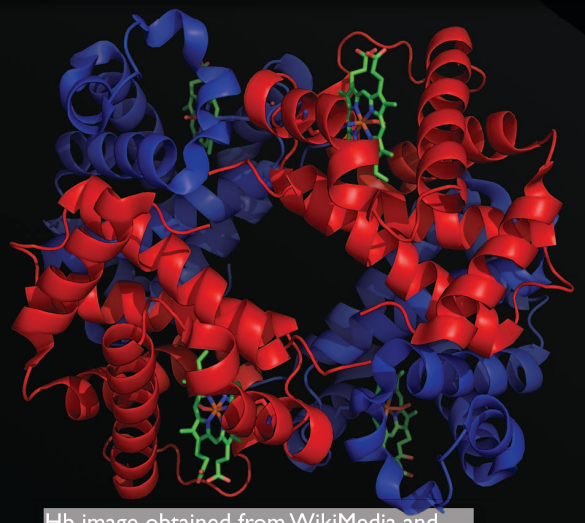
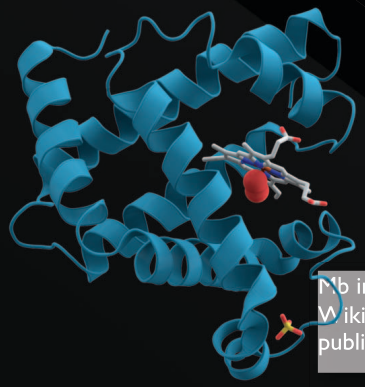
NIRS is validated for real-time monitoring of brain and muscle oxygenation and haemodynamics.

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

*Shadgan et al. *Spectroscopy*, 2009.



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



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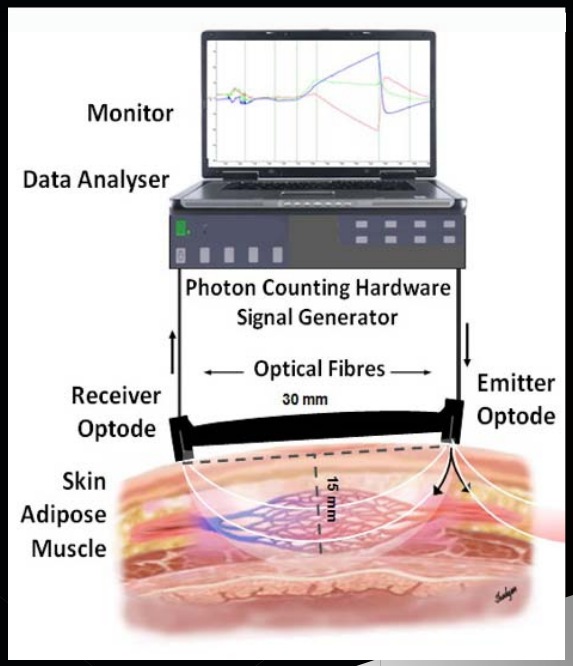
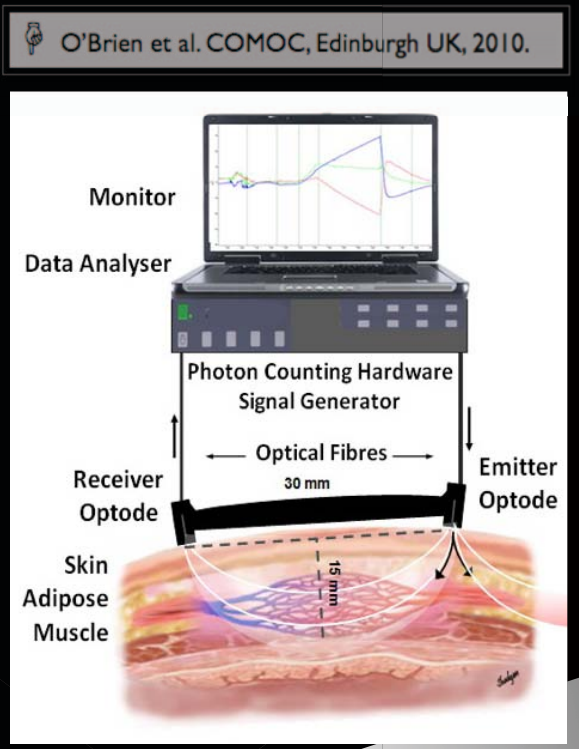


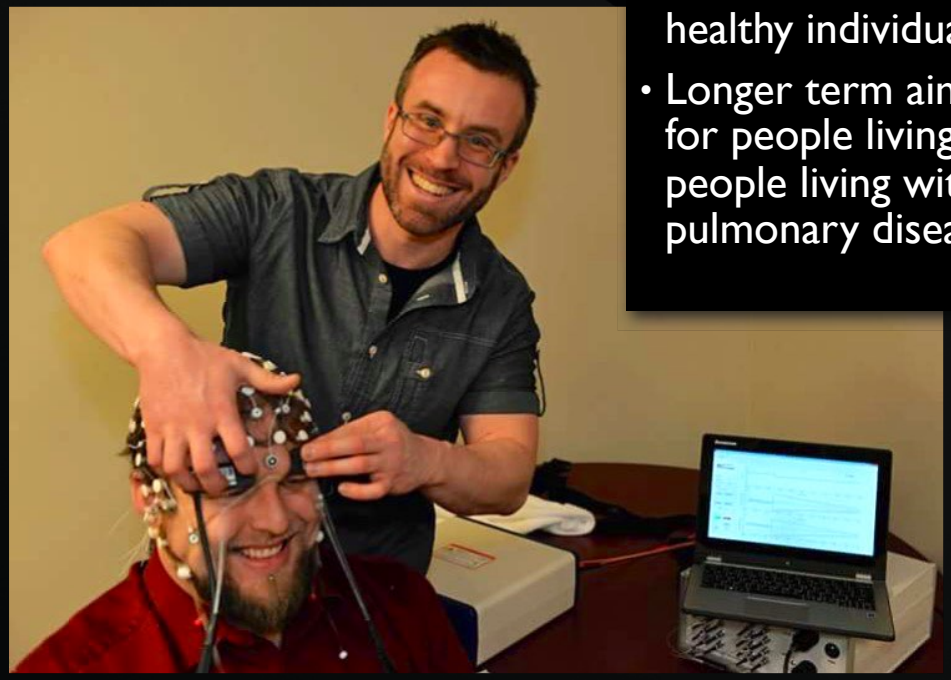
NIRS is validated for real-time monitoring of brain and muscle oxygenation and haemodynamics.

- Tissue penetration depth is ~½ 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.



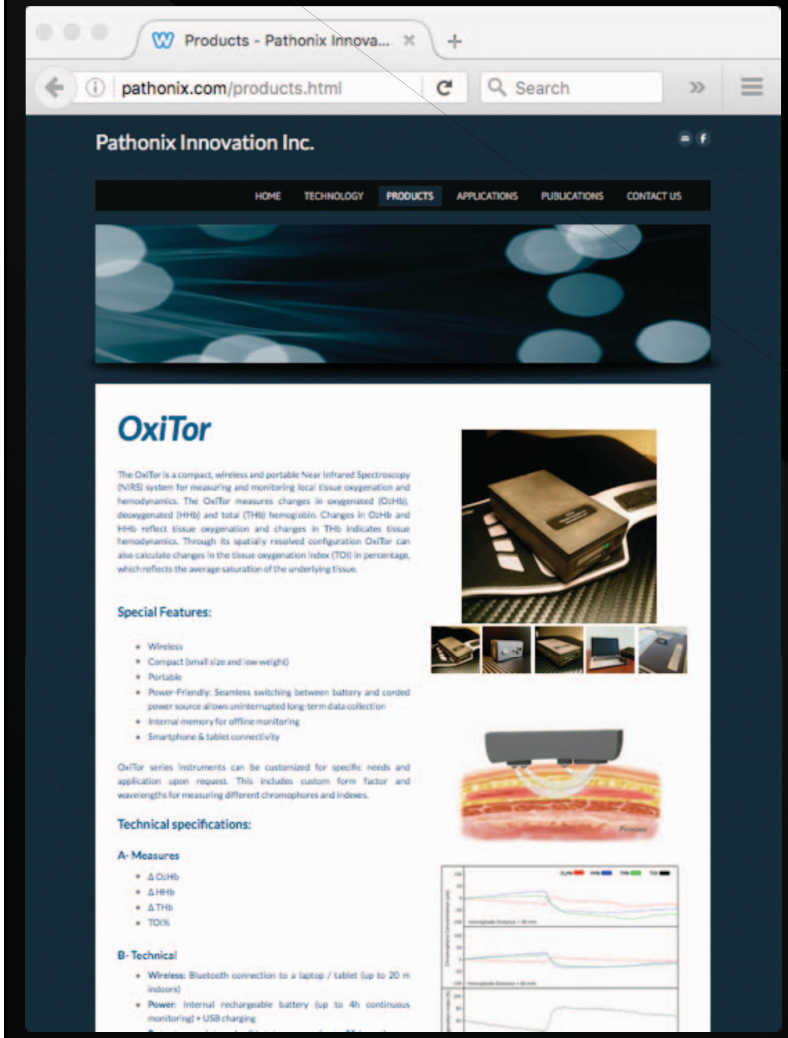
Northern BC Near-Infrared Spectroscopy Lab

- 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

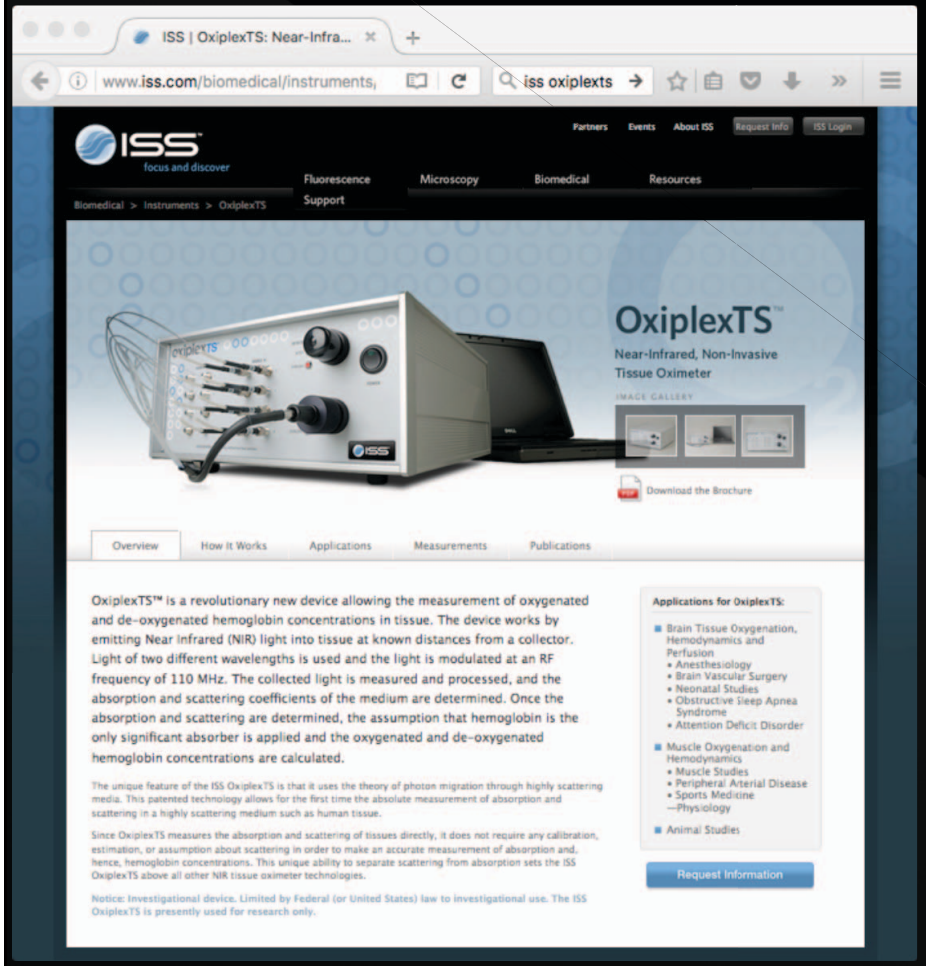
- Funded by infrastructure support from
  - Canada Foundation for Innovation and the British Columbia Knowledge Development Fund (matching funds)
  - UNBC College of Arts, Social and Health Sciences
  - UBC Northern Medical Program
  - Generous discounts from our suppliers



Northern BC Near-Infrared Spectroscopy Lab

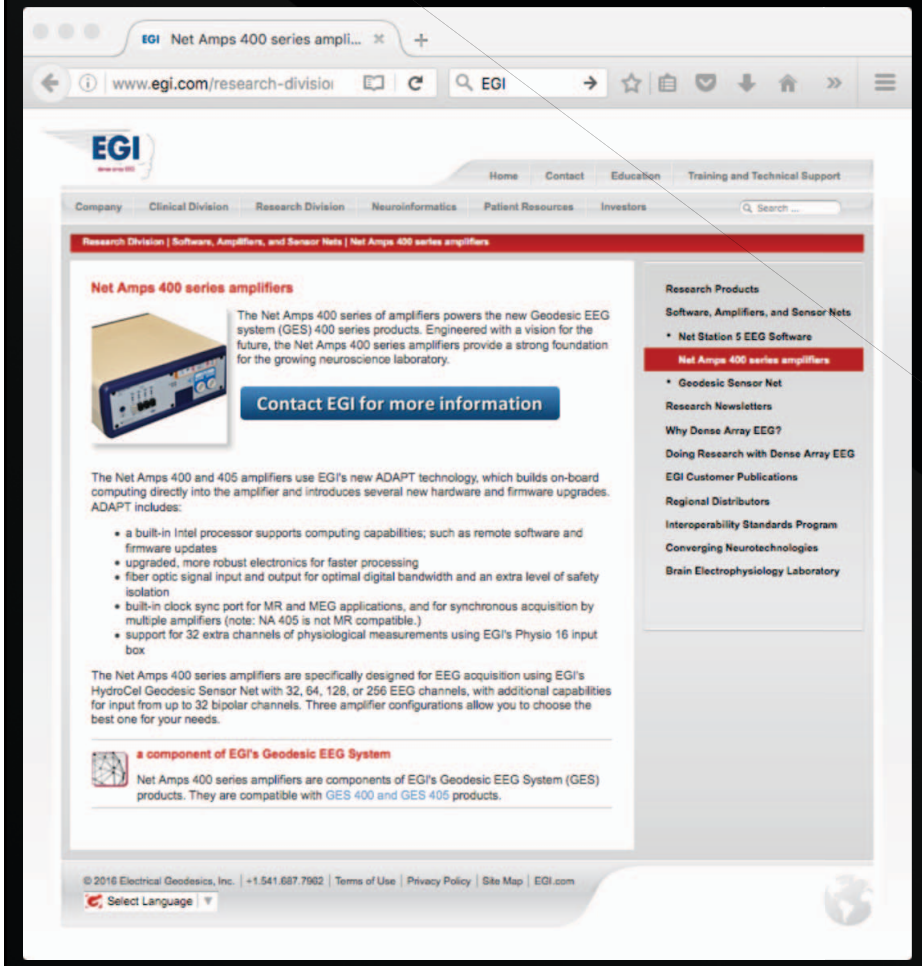
- Our equipment
  - Four portable, wireless OxiTor M2 NIRS instruments supplied by Pathonix Innovation, Inc., a Vancouver startup who are the only Canadian designers/builders/vendors of wireless NIRS instruments.
  - Used exclusively for muscle measurements.
  - Primary limitation is that it is a "spatially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

Northern BC Near-Infrared Spectroscopy Lab



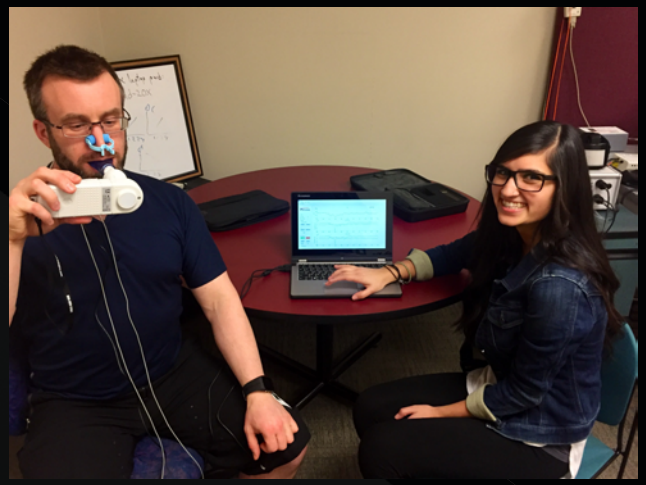
- Our equipment
  - A 2-channel, frequency-domain OxiplexTS instrument from ISS, Inc. (Champaign, IL)
  - Can be used for brain and muscle measurements.
  - Considered a "gold standard" NIRS instrument as the patented frequency-domain configuration permits absolute measurements.
  - However, it is not 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



- 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 [1]Psychology Department and [2]School of Health Sciences, [3]UBC

Northern Medical Program

Special thanks to J Jantzen and K Takaoka

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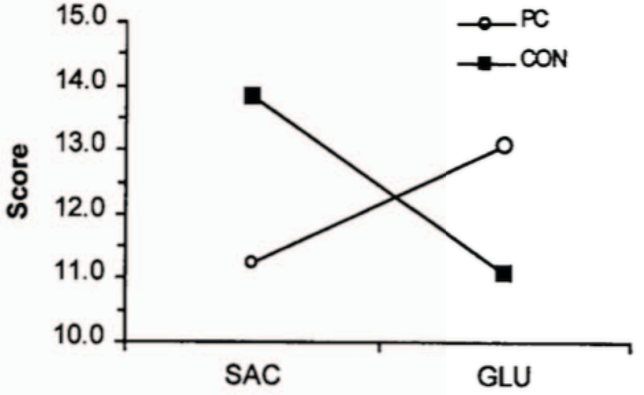

Figure 4. Performance on the Logical Memory Scale-Delayed (LMS-D) of previously concussed (PC) and control (CON) participants on glucose (GLU) and saccharin (SAC) days.

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.

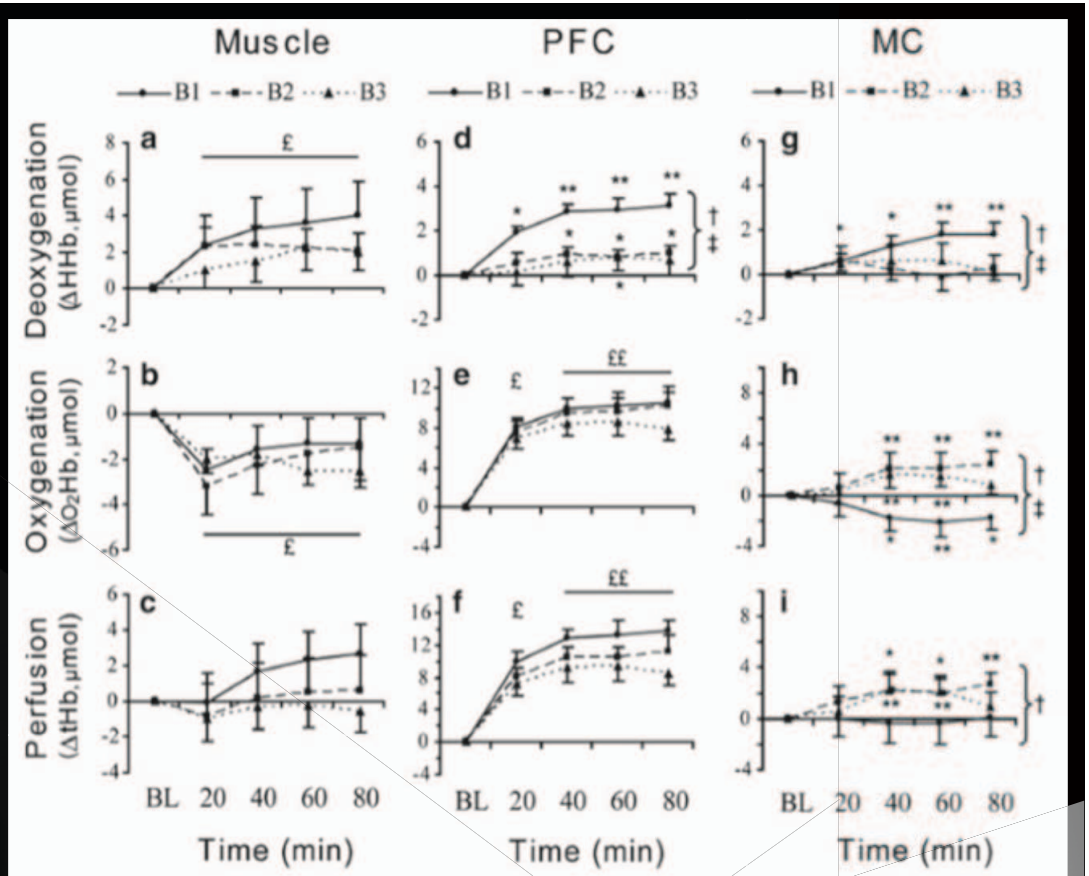

Fig. 21.1 Changes in oxy-([HbO_2]), deoxy-([HHb]), and total hemoglobin ([THb]) from BL during each of the first (B1), second (B2), and third (B3) exercise bouts. Results are shown for the *vastus lateralis* muscle (*left panels*), for the prefrontal cortex (PFC, *middle panels*), and for the motor cortex (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 ☞

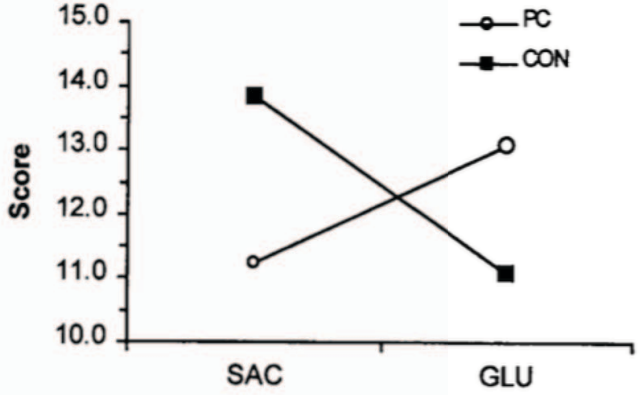

Figure 4. Performance on the Logical Memory Scale-Delayed (LMS-D) of previously concussed (PC) and control (CON) participants on glucose (GLU) and saccharin (SAC) days.

- 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.

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

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- Developed by Paul Siakaluk (2006), the SCT requires participants to distinguish between words that have high versus low body-object interactivity.

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."

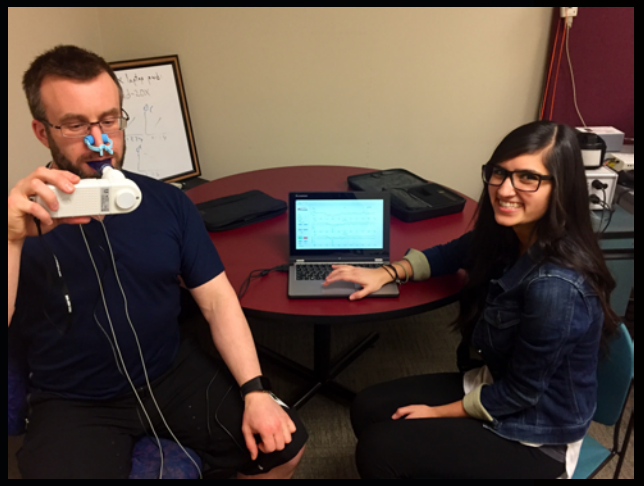
Bell L, 2016 Undergraduate Honours Thesis

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 Adapations 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!

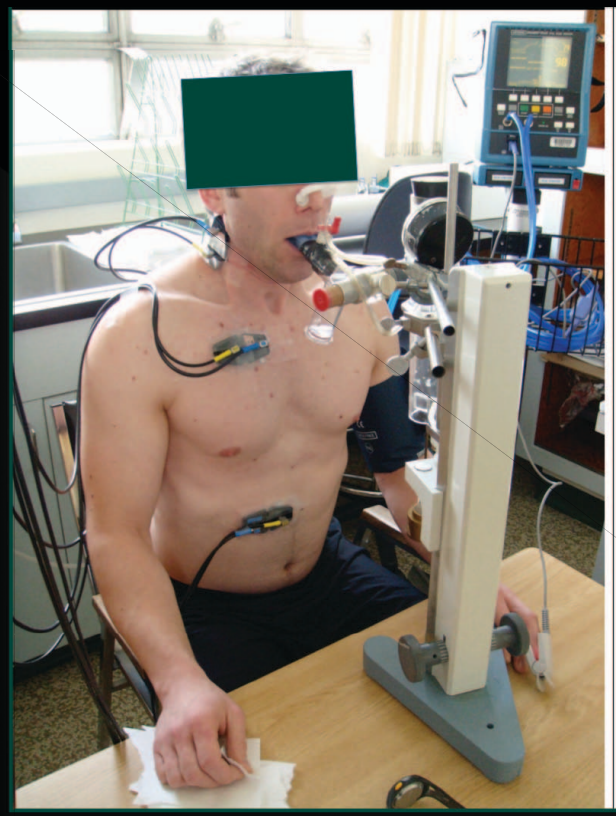


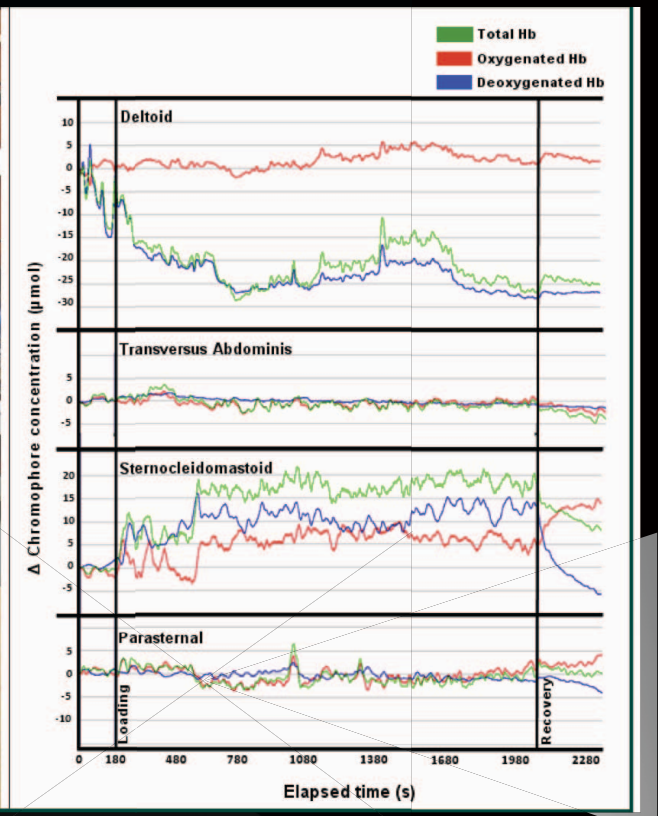
Respiratory Muscle Adapations to Detraining in Competitive Soccer Players

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 Adapations 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.

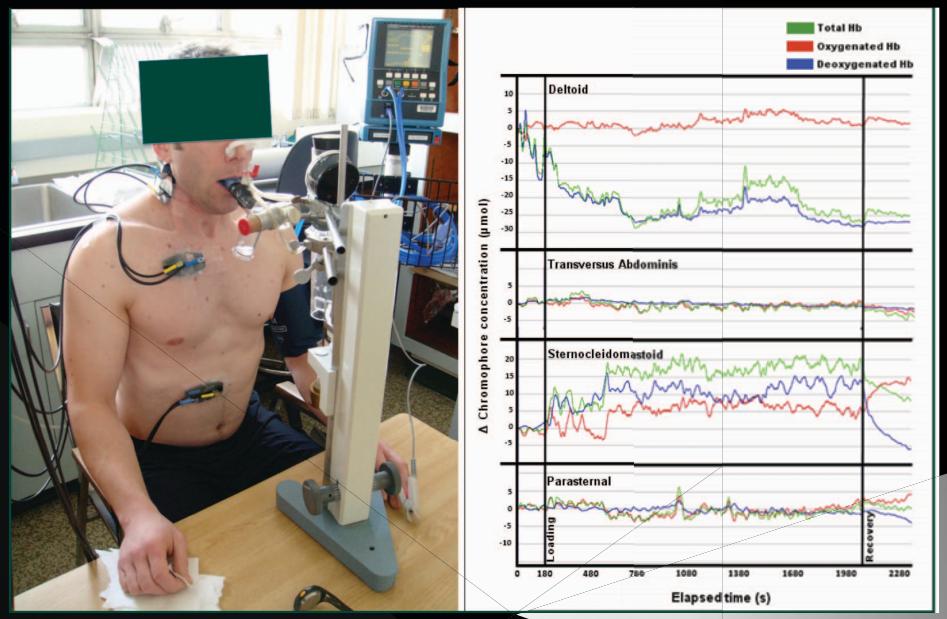
Respiratory Muscle Adapations to Detraining in Competitive Soccer Players

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

Respiratory Muscle Adapations 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 adapations in lung health.



Thank you!

Questions?

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- 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).