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BIOPHOTONIC TECHNIQUE TO STUDY MUSCLE TISSUE METABOLISM OF ATHLETES

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Introduction. Near Infrared Spectroscopy (NIRS) is one of the biophotonic techniques which can be used to monitor oxygenation and haemodynamics in a variety of human tissues, including skeletal muscle. Due to the differing light absorption properties of oxygenated haemoglobin ($Hb0_2$) and deoxygenated haemoglobin (HHb), in the near-infrared range of the electromagnetic spectrum (see Figure 1), shining light into the tissue can yield information relating to the concentrations of each form of the chromophore. This technique is entirely non-invasive, and provides real-time, in-vivo information relating to changes in oxygenation of the tissue. It also provides a measure of blood volume changes in the tissue, by reporting alterations in total concentration of $Hb0_2$ + HHb, to give a measure of total haemoglobin (tHb). NIRS has been used in a sports and exercise science setting for a number of decades, and has provided insights into changes in muscle oxygenation (StO_2) during a wide range of exercise modalities [1]. The feasibility of conventional NIRS in monitoring the pattern of skeletal muscle chromophore changes during rest, isometric exercise and ischemia is reported by different investigators [2]. This paper will provide an overview and analysis of the new portable, wireless OxyPrem device based on NIRS in elite sport and potential its application in wrestling science. To maximize training for wrestling competition, coaches and wrestlers are interested in improving the physiologic capacities that are most important for successful performance. Under the present rules for international freestyle and Greco-Roman wrestling continues 5 min match without rest and multiple matches during the day require the certain level of aerobic capacity One of most important performance parameters are oxygen consumption (mVO_2) and maximal aerobic power (VO_2max) upper and lower body muscles of wrestlers. To measure VO_2max need to use an incremental treadmill running protocol and gas exchange of CO_2 and O_2 on systemic level. But accepted methods to measure systemic aerobic power can not to reveal separate skeletal muscles performances of upper and lower body on local level. In the present work we are offering tissue oximetry (OxyPrem) to measure hemodynamic parameters of skeletal muscles (O_2Hb, HHb, tHb, StO_2, VO_2, reoxygenation rate) in rest and exercise.

Design of device. In Laboratory of Biomedical Optic (Neonatology Hospital of Zurich University, Switzerland) elaborated the new NIRS device (OxyPrem) for non-invasive measurement of localized tissue oxy- and deoxyhaemoglobin concentration ([O_2Hb], [HHb]) and tissue oxygenation (StO_2) by means of near-infrared spectroscopy [3]. OxyPrem is specifically designed for the measurement of cerebral and muscle tissue oxygenation of brain and muscles. OxyPrem a continuous-wave (CW) near-infrared spectroscopy (NIR) device with a function principle similar to the well-known and widely applied pulse oxymeters. Light in the near-infrared spectrum (NIR light), i.e. with a wavelength between 650 and 1000 nm, is emitted into living tissue and detected after its transmission. From the absorption in tissue (i.e. the difference of emitted and detected light intensity), the concentration of oxyhaemoglobin and deoxyhaemoglobin can be calculated, since the absorption properties of these substances are known and the absorption effects of other substances can be neglected. OxyPrem is attached on the bare skin over the tissue of interest (brain or muscle). After powering-up OxyPrem, it can be connected to an OxyPrem-CAU (a notebook computer with a Bluetooth antenna) and the data acquisition software Tubis installed. Tubis records the raw light intensity signal as detected by the light detectors of OxyPrem. The data are stored as a table of values in clear-text representation (in the so called comma separated values CSV format) which can be exported and analyzed offline to compute [HHb], [O_2Hb], and StO_2. This raw-data file also contains records of the movements of the OxyPrem sensor-head as measured by a 3-axis accelerometer on the OxyPrem sensor-head. Tubis controls the OxyPrem sensor remotely via a Bluetooth link. Tubis enables the user to initiate and terminate the measurement, to set the light source intensities to appropriate levels and to monitor the quality of the acquired signal. The wireless NIRS sensor was designed using commercially available electronic components which were mounted onto a four-layer rigid-flexible printed circuit board (PCB). The flexible parts of the PCB in combination with a highly flexible casing made of medical grade silicone enable the sensor to be aligned to curved body surfaces such as e.g. limbs or the head. It consists of the battery driven NIRS sensor which is connected wirelessly to a host computer, preferably a notebook or a personal digital assistant. The size of the sensor device is 92×40×22 mm, the weight including battery is 40 g. Four light sources and four detectors constitute the optical system. Each light source consists of two pairs of serially connected light emitting diodes (LED) To achieve a high integration density, four bare-chip LED dies were grouped together and sealed by a medical grade translucent epoxy. The light sources are driven current controlled and time multiplexed with an on-time of 120 µs per sample and a forward voltage of 4 V per diode. Although LEDs have a broader emission spectrum than lasers, they have several advantages: they can be applied directly on the body surface without need for lenses or fibers and they are inexpensive. Furthermore, they are harmless for the eye, which is an important advantage in a clinical environment. Four PIN silicon photodiodes in combination with transimpedance amplifier stages are used as detectors. The time multiplexed acquisition enables the background light intensity to be subtracted from the total incident light intensity, which is the superposition of LED and background light final section will examine the development of wearable NIRS devices, and the new avenues of scientific investigation which such development has permitted.

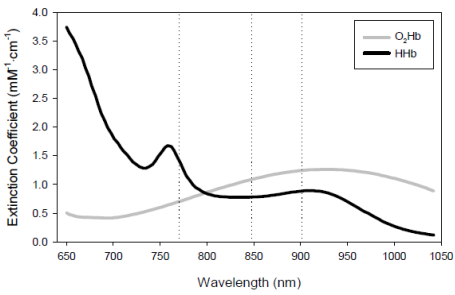

Figure 1. Absorption spectra of HbO2 and HHb in near infrared wave range

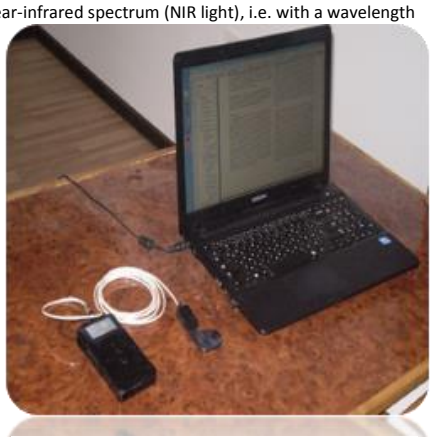

Figure 2. View of portable OxyPrem device.

Results and potential applications. *Oxygen consumption*. Measurement of muscle O_2 consumption is of great importance in the investigation of *in vivo* skeletal muscle metabolism. Whereas the more conventional techniques like strain-gauge plethysmography combined with blood gas analysis are invasive and provide regional values of the total limb, therefore, including other than muscle tissue, NIRS is noninvasive and measures local oxygenation directly in the muscle. Using venous occlusion,
VO_2 is calculated from the rate of increase in HHb (Fig. 3A) since venous outflow is blocked and the increase in HHb is thought to be solely due to the O_2 consumed. Calculation of VO_2, from arterial occlusion assumes that tHb remains constant and can then be derived from the rate of decrease in O_2Hb (Fig. 3B). Obstruction of inflow and outflow results in a static compartment of blood where the decrease of O2 from OHb is directly related to consumption.

Blood flow. Venous occlusion is used to provoke a blood volume increase in the part of the limb distal from the pneumatic cuff. Within the initial period of the occlusion, the increase in blood volume per time is a measure for the blood flow. All accepted strain-gauge plethysmography measures blood volume changes in limb circumferencebut can not distinguish between the various tissues of the limb [4]. NIRS measures blood volume changes directly in the muscle of interest by monitoring changes in the haemoglobin/myoglobin content. Blood flow (BF) in arm or leg can be measured during venous occlusion by evaluating the linear increase in tHb within the first seconds of the venous occlusion (Fig. 3A).

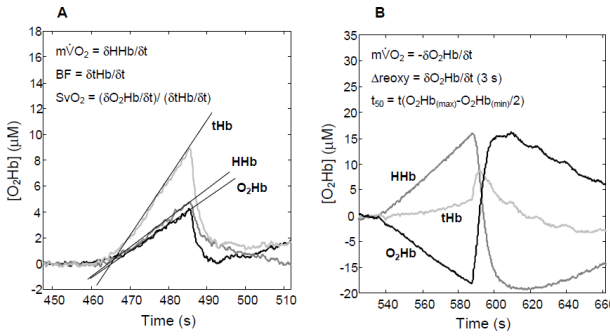

Fig.3. Quantitative NIRS measurements during A: venous occlusion and B: arterial occlusion. During venous occlusion blood flow (BF), muscle oxygen consumption (mVO_2), venous saturation (SvO_2) can be calculated. Using arterial occlusion it is possible to calculate mVO_2, reoxygenation rate (ΔO_2Hb), half recovery time (t_{50}).

Venous oxygen saturation. Another variable that can be derived from venous occlusion is peripheral venous oxygen saturation (SvO_2). With the measurement of SvO_2 direct information about O_2 extraction can be derived. SvO_2 can be calculated from the ratio of increase in ΔO_2Hb to increase in ΔtHb during venous occlusion (Fig.3A). *Half-recovery time*. The recovery of O_2Hb after exercise or ischemia represents the time needed for resaturation of deoxygenated haemoglobin and myoglobin and is thought to reflect both the influx of oxygenated arterial blood and the continued consumption during recovery. Two different approaches are known to calculate half-recovery times from NIRS signals. The first approach was described by Chance et al. [5] as the time needed for half recovery of O_2Hb from maximum deoxygenation at the end of occlusion to maximum re-oxygenation during hyperaemia (Fig.3B). *Reoxygenation rate.* Another variable that can be calculated in relation to recovery from arterial occlusion or exercise is the rate of O_2Hb reoxygenation. Whereas the half-recovery is a function of time, the reoxygenation rate reflects the velocity at which the recovery starts off after release of exercise or ischemia. This variable reflects the initial inflow of O_2Hb over a fixed time period and is, therefore, not influenced by the presence or absence of a hyperaemic response. Whereas the recovery time (or half-recovery time) includes all processes for total recovery of vascular O_2Hb, muscular O_2Mb as well as the continued oxygen consumption during recovery, the reoxygenation rate is thought to reflect the fast initial recovery rate at which primarily vascular components are restored.

Isometric brachioradialis muscle contraction. *Protocol of experiment.* Then male volunteers age 23.2±0.84 and eight female age 22.0±1.0 were recruited among wrestlers and interview to exclude any conditions that could affect their ability to perform forearm vascular occlusion test (VOT) and isometric exercise protocol of experiment.. *Brachioradialis* muscle of each individuals was identified and marked and NIRS sensor head has been placed over marked point. Next, subjects undergoes isometric handgrip contractions (3 min) and after rest time (3 min) has been measured hemodynamic parameters of muscle under investigation by VOT.

Results. Table 1 shows mean age, height, weight, maximal voluntary contraction (MVC) and skin fold thickness (SFT) of volunteers. The first trials was connected with arterial occlusion test.

Table 2. Anthropometric parameters of volunteers

	Age, (years)	Height (cm)	Weight (кg)	MVC (кg)	SFT, (cm)
Men	23.2±0.84	177.4±1.34	66.4±6.35	35.4±3.97	0.43±0.05
Women	22.0±1.0	164.2±6.06	46.6±2.88	19.8±4.02	0.24±0.04

Figure 2B show almost linear decreasing of StO_2 during AO and resaturation after occlusion release. We can see same behavior of O_2Hb and opposite trend of HHb. During the ischemia phase similar decreasing of StO_2 and O_2Hb and an equal and opposite increase in HHb were observed, while tHb tended to remain stable or slightly increase. Second trial has been connected with similar behavior we observed for tHb, O_2Hb, HHb and StO_2 during the 3 sets of isometric voluntary forearm muscle contraction at 10, 30 and 50% of MVC. Figure 4 show typical behavior of hemodynamic parameters (O_2Hb, HHb and tHb) and StO_2 during experiment. Each isometric contraction decreased muscle blood flow by increasing intramuscular pressure and compressing the small intramuscular blood vessels; tHb fell while O_2Hb decreased and HHb increased. Some variation in the magnitude of change was demonstrated between subjects. ***Conclusion.*** Two kinds of forearm muscle stimuli (VOT and isometric muscle contraction (IMC)) have similar mechanism connected with blood micro vessels pressing by around muscular filaments. Oxygen consumption rate possible to measure directly via slope of desaturation phase of blood hemoglobin during beginning stage of stimuli (VOT or IMC). Oxygen consumption rate indicate to metabolism of muscle tissue under investigation. Reoxygenation rate shortly after stimuli release is indicator of blood vessels integrity and its functionality. Reactive hyperemia is indicator of vascular reserve of muscle tissue under investigation.

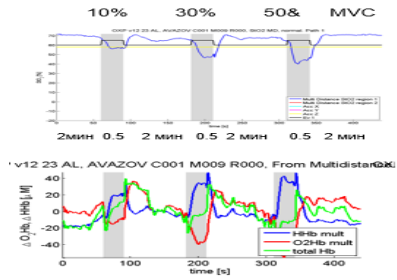

Figure 4. Behavior of hemodynamic parameters during successive 3 sets of isometric voluntary contractions of muscles at 10, 30 and 50% of MVC.

Literature

1. M. Wolf, M. Ferrari and V. Quaresima, Progress of near-infrared spectroscopy and topography for brain and muscle clinical applications, J. Biomed. Opt. 12(6) (2007), 062-104.
2. V. Quaresima,. Lepanto and M. Ferrari, The use of near infrared spectroscopy in sports medicine, J. Sport Med. Phys. Fitness 43(1) (2003), 1–13.
3. S.J.Arri, T. Muehlemann, M. Biallas, H.U. Bucher and M. Wolf, "Precision of cerebral oxygenation and hemoglobin concentration R measurements in neonates measured by near-infrared spectroscopy", J. Biomed. Opt. 16, 047005
4. DeBlasi R.A., Almenrader N., Aurisicchio P., Ferrari M. Comparision of two methods of measuring forearm oxygen consumption (VO_2) by nea infrared spectroscopy. J. Biomed. Opt. 2, 171-173, 1997.
5. Chance B., Dait M.T., Zhang C., Hamaoka T., Hagerman F., Recovery from exercise –induced desaturation in the quadriceps muscles of elite competitive rowers . Am. J. Phys. 262, Part1: 766-775, 1992.