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Abstract link:

Evaluation of muscle aging with TD NIRS and DCS

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ABSTRACT

Muscle aging is characterized by the loss of muscle mass and strength that starts mostly after 50yr and, according to the World Health Organization (2000), it is one of the major causes of independence loss and a risk factor for the development of morbidities at older age. Early diagnosis and treatment are paramount for the progression of the disease. The "Trajector-AGE" project focuses on the study of neuromuscular decline in middle-aged and old populations. Within this project, different techniques are exploited to investigate muscle health (e.g., biopsy, electromyography, Near Infrared Spectroscopy), and among them, Time Domain Near Infrared Spectroscopy (TD-NIRS) and diffuse correlation spectroscopy (DCS) are non-invasive optical techniques which enable to assess muscle oxidative metabolism and perfusion respectively. During the project life, we plan to recruit 100 individuals to evaluate differences among the hemodynamics and microcirculation responses of the vastus lateralis to arterial occlusion and incremental cycling in different age-groups (55–60yrs, middle-aged population; 75-80yrs, old population). The main parameters extrapolated will be the time courses for oxy- (HbO_2), deoxy- (HHb), total- hemoglobin (tHb), tissue oxygen saturation (S_tO_2) and blood flow index (BFI). From these, biomarkers for the neuromuscular decline will be defined. At the time of this work, 21 subjects were already acquired. Here, we present the preliminary results from 1 healthy volunteer.

Keywords: time domain near infrared spectroscopy, diffuse correlation spectroscopy, muscle aging, perfusion, microcirculation, hemodynamics, muscle oxidative metabolism

1. INTRODUCTION

Aging is characterized by a decline in neuromuscular control and a progressive loss of muscle mass, strength, and power, leading to reduced mobility and higher hospitalization rates. However, after 50yr, the reduction of muscle strength is accelerated and becomes faster than the average muscle mass loss[1]. Exercise intolerance (defined as the incapacity to produce or maintain a muscle force that enables individuals to accomplish everyday life tasks) represents one of the clinical hallmarks of aging. Impairments in O_2 delivery and O_2 uptake at skeletal muscle level seem to represent potential mechanism of exercise intolerance in aged subjects. In this work, we employed non-invasive optical techniques for a functional monitoring of microvascular and metabolic changes occurring in the vastus lateralis. TD-NIRS[2] and DCS[3] were simultaneously used for the evaluation of muscle oxidative metabolism and microvascular blood flow, respectively, within the "Trajector-AGE" project. This project focuses on the study of neuromuscular decline in middle-aged and old populations with a series of different techniques (e.g., biopsy, electromyography) to give a comprehensive characterization of the muscular status and trace trajectory of aging during months. In this preliminary work we want to assess the capability of the two optical techniques, TD-NIRs and DCS, to be able to work together during standard protocols. In particular, we will focus on two critical phases of aging: 55–60yrs (middle-aged) and 75-80yrs (old). Within each age-group, subjects will be classified based on their functional capabilities and divided into either active or sedentary. Up to now, 21 subjects from across these groups have been already measured, while 100 subjects will be overall enrolled within the project lifetime. Here, we present the preliminary results from 1 healthy volunteer.

2. MATERIALS AND METHODS

Before attending the measurement sessions, subjects had to sign an informed consent. The protocol was approved by the Ethical Committee of Ospedale Maggiore in Parma and conducted in accordance with the Declaration of Helsinki. The measurement sessions were divided in two experiments:

    1)   Arterial cuff occlusion of the right leg. After an initial baseline (at least 120 s) a pneumatic cuff was placed at

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the inguinal crease of the thigh and inflated at a pressure of 280-300 mmHg to occlude the right femoral artery. The cuff was released when the level of oxygen saturation reached a plateau (with a maximum occlusion time of 300 s). The recovery phase was also followed for at least 180 s. During the occlusion, the subject was set down on a cycle ergometer and the leg was kept in a fixed position on the pedal.

2) Incremental cycling exercise. After an initial baseline (120 s) the subjects completed an incremental ramp test up to exhaustion, starting from unloading pedaling and then increasing the load according to the level of physical activity of each subject, until exhaustion. At the end of the exercise, a cool-down period with light pedaling was performed.

All the measurements were performed using a device previously developed at the Physics Department, Politecnico di Milano, which allows TD NIRS and DCS synchronized acquisitions[4]. During all protocols, the custom-made probe, hosting TD-NIRS and DCS optical fibers, was placed on the vastus lateralis muscle and fixed with a black auto-adhesive bandage. The source-detector distances were set to 2.5 cm for both TD-NIRS and DCS modules.

Time series for the following parameters were calculated with 1 Hz sampling rate and expressed as absolute values: oxy- (HbO_2), deoxy- (HHb) and total- (tHb) hemoglobin concentration, measured in μM; tissue oxygen saturation (S_tO_2), and blood flow index variation from the baseline (BFI), expressed in %. Data were analyzed using the solution of the diffusion equation for a homogeneous semi-infinite medium, suitable to describe photon diffusion in biological tissues.

3. RESULTS

Up to now, 21 volunteers (13 females, 8 males) were measured (65.6±10.4 years). Data from a representative subject are reported in Fig. 1, where the time courses for the hemodynamic and perfusion parameters during the arterial occlusion (panels a), b) and c)) and the incremental cycling exercise (panels d), e), f)) are shown.

As expected[4], during the occlusion HHb progressively increases while HbO_2 decreases. Thus, tHb shows a slight increase, and S_tO_2 exhibits an almost linear reduction. On the other side, BFI drops to zero as soon as the cuff is inflated. At the end of the occlusion, the hyperemic peak is observed in tHb, S_tO_2 and BFI. During incremental cycling exercise, similar trends are observed for HHb and S_tO_2, while HbO_2 remains almost constant, resulting in an increase in tHb. BFI exhibits opposite behavior, abruptly increasing at start of the exercise, in accordance with previous findings[5].

4. DISCUSSION AND CONCLUSIONS

We reported the muscle oxidative metabolism and microvascular perfusion measured in a single subject, as case study. As a general remark, we note that, while occlusion tests are a well-consolidated protocol for both BFI and S_tO_2, only few studies have been performed on BFI variations during cycling[5], probably due to the well-known sensitivity of DCS to motion artifacts. Thus, we will exploit the measurements performed in this study to go in depth about this point. Moreover, the measurements were carried out using a single interfiber distance for both TD-NIRS and DCS modules, which does not enable to discriminate shallow from deep microvascular blood flow. To address this limitation, we are developing a new multi-distance hybrid device that allows to perform simultaneous TD-NIRS and DCS measurements at two source-detector separations (1.5 cm and 2.5 cm). This device will be soon exploited in this project to increase the sensitivity to muscle hemodynamic variations. We will recruit more volunteers (100 individuals) to reinforce our statistics and evaluate differences among the hemodynamics behavior within age-groups.
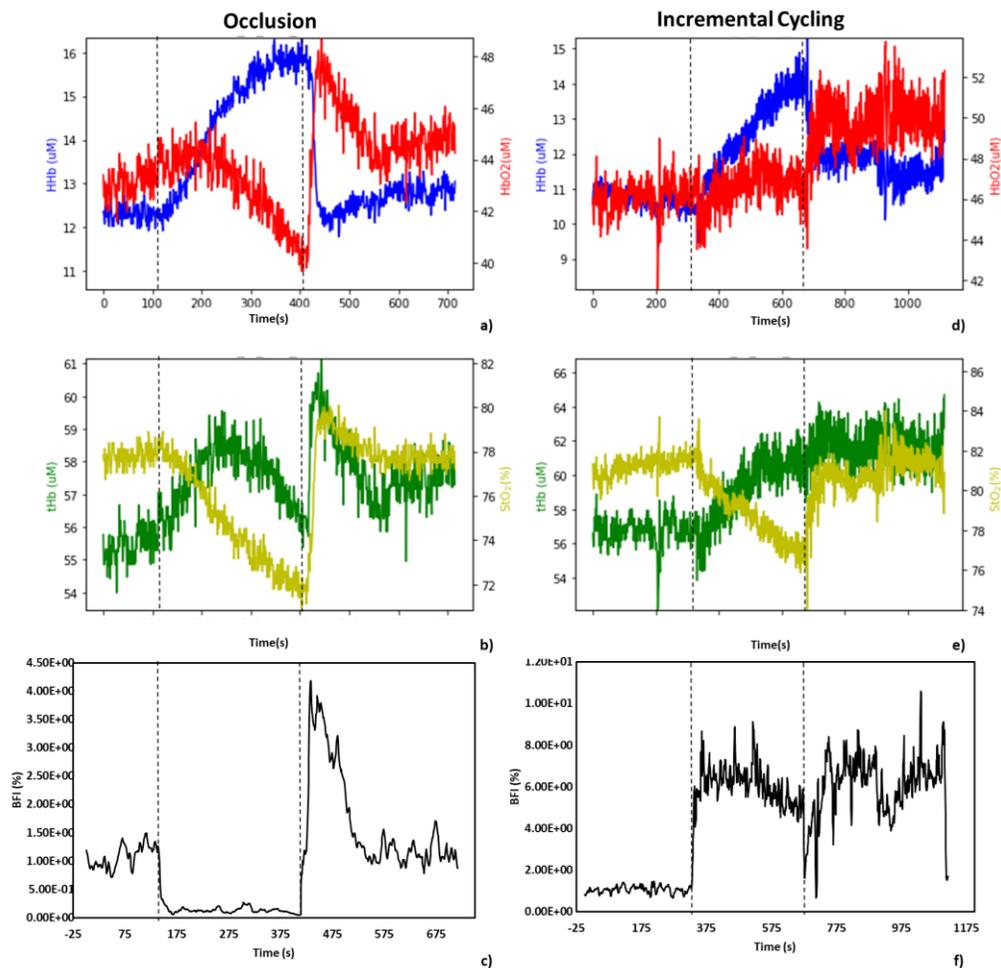
Figure 1. Muscle oxidative metabolism and microvascular time courses during arterial occlusion (on the left) and incremental cycling (on the right). Panels a) and d) oxygenated (HbO₂) and deoxygenated (HHb) hemoglobin; panels b) and e) tHb and S₂O₂; panels c) and f) blood flow index (BFI); black dashed lines represent the start and the end of the protocols.

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