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Vastus Lateralis Muscle's Characterization on bedridden patients: a Time Domain fNIRS study

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Abstract: The vastus lateralis muscle was characterized by means of time-domain near infrared spectroscopy on 28 bedridden elderly patients. Optical and hemodynamics parameters were evaluated together with age, adipose tissue thickness and pennation angle.

1. Introduction

The elders are considered frail from a skeletal-muscular point of view. As a result of falls, in particular for women who may suffer of osteoporosis, fractures of the femur may occur and surgery is often required [1]. As a consequence, long period of bed rest is required, which cause a deterioration of muscle ability in the whole body and in particular in the inferior arts. In this contest, there is still a lack in the clinical environment of techniques which could provide a quantitative and objective evaluation of the muscular status during the bed-rest. In this work we propose the monitoring of the vastus lateralis muscle during an isometric exercise on a bedridden population in order to characterize this muscle from an optical and oxidative metabolism point of view. In particular, we will focus on the optical properties (absorption and reduced scattering coefficients) and the hemodynamic parameters (oxy-, deoxy-, total- hemoglobin and tissue oxygen saturation) during the initial rest period of the exercise. To this purpose, we employ time domain (TD) near infrared spectroscopy (NIRS), an optical technique which allows to measure the absolute values of the above-mentioned parameters, and we consider only the deeper part of the investigated tissue, i.e. the muscular fibers, and not the more superficial layers, i.e. skin and fat [2,3].

2. Material and methods

The TD-NIRS acquisitions were performed with a medical device, previously developed at the Department of Physics, Politecnico di Milano and described in Re *et al.* [4]. The TD-NIRS probe was placed on the vastus lateralis of the non-surgical leg allowing the acquisition of two optical channels: one short (ρ_1=1.5 cm) and one long (ρ_2=3.0 cm) interfiber distance.

Subjects were seated on a custom chair, which allows to fix the knee angle at 120° and guarantees a safety and comfortable placement of the patient. Their ankle was fixed to a chair holder and connected to a load cell, in order to register the power exerted during the quadriceps isometric contraction at the 80% of the maximum voluntary contraction (MVC), previously determined. Subjects were required, after an initial period of 60 s of baseline, to perform a series of 20 sustained isometric contractions, composed of 10 s of contraction followed by 5 s of relaxation. The exercise ended with a 300 s of recovery period. The acquisition rate was set at 1 Hz.

During the whole acquisition, also the torque and the electromyographic (EMG) signal were acquired. An auditory stimulus was used to indicate the beginning and the end of each contraction (Presentation®, Neurobehavioral Systems Inc.), and the personalized torque threshold to reach was shown on a wide screen in front of the patient. All the stimuli and acquisitions were synchronized.

For each subject the following data were also acquired: age, MVC, adipose tissue thickness (ATT) and pennation angle (PA) at the measurement site by means of an ultrasonographic (US) exam.

The study was approved by the Ethical Committee of Istituto Ortopedico G. Pini and conducted in accordance with the Declaration of Helsinki. A total of 28 subjects were involved after having signed an inform consent; they were bedridden after surgery for femur fracture, and they have not yet started a rehabilitation program.

3. Data Analysis

In order to retrieve, from the TD-NIRS data, the optical properties of the vastus lateralis muscle (i.e. absorption and reduced scattering coefficient, μ_a and μ'_s respectively) a two-step procedure was applied. At first, the solution of the

diffusion equation for a homogenous model was applied, to retrieve μ_a and μ'_s separately for the two interfiber distances ρ_1 and ρ_2. These values were used as initial values for a second fit procedure, which is based on a bi-layer model and the knowledge of the ATT, and on the mix of the information of both the interfiber distances, for retrieving the optical parameters of the superficial (UP) layer (more related with skin and lipid) and the bottom (DW) layer (more related with the muscular fibers). With the Lambert Beer law, the tissue hemodynamic parameters were obtained for the whole experiment time: the oxy-, deoxy- and total- hemoglobin content, (O_2Hb, HHb and tHb respectively, expressed in μM), and the tissue oxygen saturation (SO_2, expressed in %).

In this work, we will focus on the muscle characterization during the baseline period. The baselines were calculated for all the signals as the average of the last 10 s of the initial rest period (60 s). A signal quality check was performed, based on the number of photons acquired and the fit procedure goodness. From the 28 acquired subjects, 6 were removed before performing the statistical analysis. Two male subjects were excluded being a too small sample for a reliable characterization, one subject had an ATT > 3cm, which is a too high value for applying the two-step procedure, and other 3 subjects were removed due to problems during the measurements (not collaborative subjects). The total number of subjects included in the following analysis was then 22 female subjects.

The following parameters were considered for a statistical analysis: AGE, ATT, PA, MVC, μ_a, μ'_s, O_2Hb, HHb, SO_2 and tHb. In particular, the population distributions for each parameter were represented with boxplots and the mean, average and standard deviation were calculated. Relations between all different parameters were investigated with Pearson coefficients correlation and one-way Anova analysis. In the following the values will be expressed as average ± standard deviation.

4. Results and discussions

The mean age of the 22 female subjects in our final population was 78.2±6.7 years. The measured ATT was 10.8.2±4.0 mm and the PA 8.2±4.4 °. The exerted MVC was 295.6±106.7 W. In Table 1, the optical properties and the hemodynamic parameters are shown for the DW layer.

Table 1. Optical characterization for the DW layer of the vastus lateralis muscle. μ_a= absorption coefficient, μ'_s = scattering coefficient, RED and IR= red and infrared wavelengths, O_2Hb= oxy-hemoglobin, HHb= deoxy-hemoglobin, tHb= total-hemoglobin, SO_2= oxygen saturation.

	μ_a (RED) [cm^{-1}]	μ_a (IR) [cm^{-1}]	μ'_s (RED) [cm^{-1}]	μ'_s (IR) [cm^{-1}]	O_2Hb [μM]	HHb [μM]	tHb [μM]	SO_2 [%]
Average	0.15	0.15	8.76	8.07	46.5	25.3	71.8	65.3
Stdev	0.06	0.05	0.73	0.72	13.5	10.1	22.6	4.8
Median	0.14	0.14	8.61	7.85	44.0	22.7	67.7	64.4

No correlations were found among all the parameters. We only notice that it was possible to divide the O_2Hb parameter into two subgroups based on the ATT values. The O_2Hb median for subject with ATT ≦ 9.1 mm was 56.8 μM, while its median for ATT > 9.1 mm was 37.3. These two values present a significant difference (p= 0.0005). A similar behavior was obtained for the HHb and tHb parameters. These results could be due to the fact that increasing the ATT, it is possible to have an underestimation of the absorption coefficient of the DW layer. This behavior is, in fact, confirmed by the absorption coefficient, which shows the same trend, and by the scattering coefficient, which on the contrary does not follow it.

5. Conclusion

In this work we reported an optical characterization of the muscular tissue of a population of elderly people who underwent surgery and was bedridden. This work is important, since nowadays no techniques providing an objective assessment of the oxidative status of a muscular tissue are routinely used in clinics. Furthermore, work is in progress to compare the basal muscular characterization presented here with that observed during the recovery period after the exercise.

6. References

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