Microvascular hemodynamics in climbers during a vascular occlusion test

Blai Ferrer-Uris[1]*, Albert Busquets[1], Faruk Beslija[2], Turgut Durduran[2,3]

[1]Institut Nacional d'Educació Física de Catalunya (INEFC), Universitat de Barcelona (UB), Barcelona, Spain
[2]Institut de Ciències Fotòniques (ICFO), Barcelona Institute of Science and Technology (BIST), Castelldefels (Barcelona), Spain
[3]Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain.

Introduction

Local endurance of the finger flexors has been associated with the ability to deliver and use oxygen within the muscle. The studies of oxy- and deoxyhaemoglobin concentrations in muscle have become possible due to photonics-based technologies, such as Near Infrared Spectroscopy (NIRS). NIRS has been used in climbers during vascular occlusion tests (VOT) to assess the hyperaemic response of the forearm muscles. Previous studies have related the climbing performance to the half-time for tissue oxygen re-saturation (O_2HTR) following ischemia [1]. Diffuse Correlation Spectroscopy (DCS), another photonics-based technology, allows one to measure the mean square displacement (MSD) of the red blood cells within the muscle microvasculature, providing a measure of the blood flow index (BFI), a relative value equivalent to the mean blood flow within a tissue volume through which the light diffuses [2]. Combined usage of NIRS and DCS could provide new insights into climbing-specific adaptations. The present study aimed to describe the relationship between tissue oxygenation and the blood flow dynamics during VOT and to compare both dynamics between climbers and non-climbers.

Method

Seventeen advanced climbers (7 female; 7a-8c+/9a redpoint grade on French scale, 20.4 ± 3.2 redpoint grade on IRCRA scale) and 15 healthy active non-climbers (7 female) participated in the study. NIRS (PortaLite, Artinis Medical Systems) and custom DCS (Institut de Ciències Fotòniques) were placed along the flexor digitorum profundus (FDP) muscle of the dominant arm of the subject, to measure concentrations of oxyhaemoglobin (O_2Hb) and deoxyhaemoglobin (HHb), Tissue Saturation Index (TSI) and BFI during VOT. After resting in the supine position for 17 minutes, the VOT protocol was initiated. VOT protocol consisted of a 3-minute baseline measurement (BS), followed by the tourniquet-induced ischemia at the brachial artery, where the tourniquet was quickly inflated to 220 mmHg, and the pressure was maintained until the TSI obtained from NIRS stabilized for 30 seconds (occlusion measurement, OC). Finally, the tourniquet was rapidly deflated and NIRS and DCS data were collected for 3 more minutes (reactive hyperaemia, HY, and recovery measurements, RE). Mean baseline values of the oxygenation signals (BS-O_2Hb, BS-HHb, BS-TSI) were obtained from 1 minute of the BS and were used to compute the delta (Δ) values from the subsequent oxygenation variables (Figure 1). For the OC, oxygenation signals were used to calculate: the linear slope of the initial 20 seconds of the occlusion after the tourniquet inflation (OC-O_2Hb_{slope}, OC-HHb_{slope}, OC-TSI_{slope}), peak value (OC-ΔO_2Hb_{min}, OC-ΔHHb_{max}, OC-ΔTSI_{min}), and time-to-peak (OC-O_2Hb_{tmin}, OC-HHb_{tmax}, OC-TSI_{tmin}). The minimum value of BFI during OC (OC-BFI_{min}) was computed as the mean of the last 10 seconds before the release. For HY upon tourniquet deflation, the following variables were extracted: peak hyperaemic value (HY-ΔO_2Hb_{max}, HY-ΔHHb_{min}, HY-BFI_{max}, HY-ΔTSI_{max}), time-to-peak hyperaemic value (HY-O_2Hb_{tmax}, HY-HHb_{tmin}, HY-TSI_{tmax}, HY-BFI_{tmax}), linear slope from tourniquet release to peak values (HY-O_2Hb_{slope}, HY-HHb_{slope}, HY-TSI_{slope}, HY-BFI_{slope}), and elapsed time from the tourniquet release to half of the height of the hyperaemic response (HY-O_2Hb_{HTR}, HY-HHb_{HTR}, HY-TSI_{HTR}, HY-BFI_{HTR}). Finally, RE was characterized by the linear slope from the hyperaemic peak response to the signal value 30 seconds after this peak (RE-O_2Hb_{slope}, RE-HHb_{slope}, RE-TSI_{slope}, RE-BFI_{slope}). The relations between the oxygenation and the BFI variables were explored through Pearson's correlation coefficient using data from both groups together. Differences between groups were explored through independent samples T-test or Mann-Whitney U test for non-parametric variables. Only statistically significant results ($p \leq 0.05$) were reported.

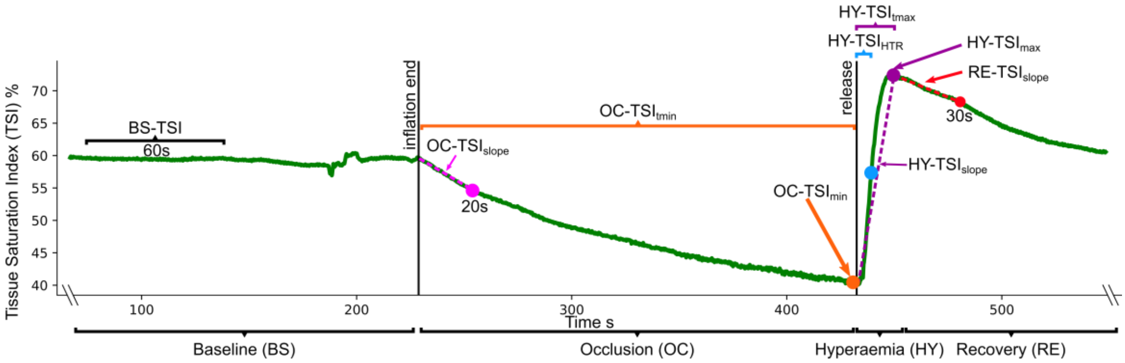

Figure 1. Schematic representation of the calculated variables

Results

Significant correlations between oxygenation and BFI variables and differences between groups were found only during release measurements. HY-BFI_{tmax} and HY-BFI_{HTR} were positively correlated with its O_2Hb (r=0.718 and r=0.542, respectively), HHb (r=0.398 and r=0.540, respectively), and TSI (r=0.575 and r=0.567, respectively) equivalents. Climbers presented greater HY-ΔO_2Hb_{max} (t=3.578, d=1.268) and HY-BFI_{max} (u=77.0, d=0.759) and lower HY-ΔHHb_{min} (t=-2.798, d=0.991) values than non-climbers. Moreover, HY-O_2Hb_{slope} (t=2.372, d=0.840) and HY-BFI_{slope} (U=82.0, d=0.695) were also greater for climbers. During the initial recovery after hyperaemia, RE-BFI_{slope} was positively related to RE-TSI_{slope} (r=0.378) and RE-O_2Hb_{slope} (r=0.438). During RE, climbers presented greater slopes for all parameters: RE-O_2Hb_{slope} (t=-4.975, d=1.727), RE-HHb_{slope} (U=61.0, d=0.612), and RE-TSI_{slope} (U=77.0, d=0.279), RE-BFI_{slope} (U=80.0, d=0.695).

Discussion

Our data showed a positive association between the timing (time-to-max and HTR) of BFI and that of the O_2Hb, HHb, and TSI during reactive hyperaemia. These findings could indicate that the timing of the reactive response may be greatly dependent on the restitution of the blood flow and the magnitude of the microvascular dilation caused by the ischemia. This supports previous research that has related the timing and slope of the hyperaemic response to the endothelial function [3]. Similarly, the relation between BFI, TSI, and O_2Hb found in the slopes after the hyperaemia could indicate that the initial recovery dynamics may be partially driven by the autoregulation of the blood flow, initiated by the sudden increase in the intravascular pressure and shear stress after the tourniquet release. In addition, greater maximum values and steeper up-slopes in BFI and O_2Hb and lower HHb values after the tourniquet release exhibited by the climbers indicated an improved endothelial function in locally trained subjects [3]. Similarly, initial recovery slopes of the oxygenation and the BFI parameters in climbers showed a faster post-hyperaemic recovery, which could indicate that climbers present greater blood flow autoregulation, better venous circulation, and, possibly, better oxidative capacity than non-climbers.

References

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Short Biography

Dr. Blai Ferrer-Uris is a full-time professor at INEFC-UB. He is currently focused on the use of NIRS and DCS participating in several funded projects aiming to study how to optimize Blood Flow Restriction training via photonics (AES-ISCIII, DTS22/00023; CSD, EXP 75094) and the effects of physical exercise on motor learning and brain activity (ExLe-Brain-DCD, PID 2020-120453RB-I00).