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Book of Abstracts

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Free Oral Communications

O1. Muscle Hemodynamics Assessment in Athletes Using TD-NIRS and DCS During Arterial Occlusion

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Objective: To evaluate whether Time-Domain Near-Infrared Spectroscopy (TD-NIRS) and Diffuse Correlation Spectroscopy (DCS) can detect training-induced changes in muscle oxygenation and microvascular hemodynamics in competitive sprinters.

Hypothesis: Training increases muscle metabolic demand and alters reperfusion dynamics, resulting in measurable changes in TD-NIRS- and DCS-derived haemodynamic biomarkers, with heavier training sessions producing larger effects than lighter sessions.

Methods: Sixteen competitive sprinters (21–28 years, 6 females and 10 males) underwent pre- and post-training measurements following both light and heavy training sessions. An arterial occlusion protocol was performed on the dominant leg. TD-NIRS was used to measure tissue oxygen saturation (StO_2), while DCS measured blood flow index (BFI) [1]. Desaturation slope was calculated between 30 and 90 s after occlusion onset. Hyperemic area under the curve (AUC) for StO_2 and BFI was quantified during post-occlusion recovery [2].

Results: TD-NIRS and DCS detected physiological changes associated with training. Across the cohort, desaturation slopes increased after exercise, indicating enhanced oxygen consumption. Mean desaturation slope changes were +18% following light sessions and +32% following heavy sessions, demonstrating greater metabolic demand after higher training loads. Hyperemic AUC did not show statistically significant differences between light and heavy training sessions. DCS-derived flow AUC exhibited greater variability because of increased sensitivity to measurement noise. Overall, the desaturation slope was the most robust parameter for distinguishing training conditions.

Conclusions: Combined TD-NIRS and DCS measurements provide a sensitive, noninvasive approach for assessing training-induced changes in muscle oxygenation, reperfusion dynamics, and microvascular function. The desaturation slope emerged as the strongest biomarker for differentiating training load, supporting the use of optical hemodynamic monitoring for individualized athlete assessment and training optimization.

O2. {mnirs}: An R Package for Reading, Processing, and Analysing Muscle Near-Infrared Spectroscopy Data

Jem Arnold

Muscle near-infrared spectroscopy (mNIRS) is a widely used tool in human physiology research, sports science, and clinical rehabilitation for non-invasive assessment of local muscle oxygenation. The availability of wearable mNIRS devices has made data collection increasingly accessible. However, data processing and analysis remain inconsistent, with centres often using ad hoc scripts and manual spreadsheets for signal processing and analysis.

Such fragmented methods limit reproducibility and hold back standardisation in the field. Here we introduce {mnirs}, an open-source R package developed specifically for mNIRS data. {mnirs} provides a standardised, reproducible pipeline for reading files, cleaning, filtering, transforming, extracting, and visualising time-series data from mNIRS devices. The package website is available at: https://jemarnold.github.io/mnirs/

Alongside the R package, a basic no-code workflow is available as a free online app: https://jemarnold-mnirs-app.share.connect.posit.cloud/. This tool is designed for researchers, practitioners, and aspiring NIRS users with minimal coding experience, emphasising accessibility, reproducibility, and transparent processing decisions.

The objective of this abstract is to introduce a new data-processing tool to the mNIRS community through an interactive demonstration of common processing tasks, including:

- Comparison of common digital filtering methods.
- Analysing deoxygenation and reoxygenation kinetics during incremental exercise.
- Microvascular responsiveness with slope- and time-based kinetics after a resting vascular occlusion.
- Muscle oxidative capacity assessment with repeated occlusions after an exercise stimulus, using monoexponential curve fitting.

O3. Distinct vastus lateralis deoxygenation profiles during maximal incremental cycling test: association with metabolic parameters

Bernabeu A. (1), Hays A. (1), Bendahan D. (2), Jue T. (3), Giraud D. (1,4), Brégeon F. (5)

INTRODUCTION:

During maximal incremental test, vastus lateralis (VL) muscle deoxygenation (HHb) measured by near-infrared spectroscopy (NIRS) typically displays a linear increase, followed by a plateau or end-attenuation before maximal aerobic capacity (MAP) [1,2]. However, breakpoint (BP) presence, timing and slope responses vary substantially across individuals [1,3,4]. Moreover, rectus femoris (RF) profile showed a different kinetic, illustrating also a BP, but followed by an increase of the HHb slope [2]. The physiological determinants underlying this heterogeneity remain poorly understood. This study aimed to better characterize the various patterns of VL HHb evolution during incremental exercise and its link with metabolic parameters and RF HHB BP.

METHODS:

A total of 22 trained male cyclists (20.71±2.10 years, $\dot{V}O_2max$: 62.73±6.45 mL·min-1·kg-1) performed an incremental test to exhaustion (100 W + 25 W·2min-1). VL and RF HHb was continuously monitored using time-domain NIRS (PIONIRS), as was gas exchange ($\dot{V}O_2$,$\dot{V}CO_2$). Ventilatory (VT1, VT2) and lactate (LT1, LT2) thresholds were determined using Beaver [5] and Skinner-McLellan [6] methods. VL and RF HHb kinetics were fitted with two independent linear regressions, BP being their intersection. Participants were classified according to the change in VL HHb slope after BP: an end-attenuation profile when the second slope was lower than the first, and a positive profile when the second slope was higher [7].

RESULTS:

Only 10 of the 22 cyclists showed an end-attenuation VL HHb profile, whereas 12 showed a positive profile. The end-attenuation group had lower LT1 (54.64 ± 5.76 vs. 60.63 ± 4.93, $p = 0.0162$) and LT2 (69.61 ± 5.47 vs. 75.60 ± 4.70, $p = 0.0120$), with no differences in $\dot{V}O_2max$, VT1, VT2, or MAP ($p > 0.05$). BP VL did not differ between groups and was correlated with RF BP ($r = 0.66$, $p = 0.0008$). No significant correlation was found between BP VL and other thresholds.

CONCLUSION:

The shape of the HHb response during incremental exercise appears to be more closely related to peripheral metabolic characteristics than to whole-body aerobic fitness. The lower lactate thresholds observed in cyclists exhibiting an end-attenuation profile suggest that post-breakpoint HHb kinetics may reflect inter-individual differences in muscle oxidative phenotype, and/or motor unit recruitment strategies rather whole-body limitations. The absence of a relationship between BP and ventilatory thresholds or $\dot{V}O_2$ further supports the idea that NIRS provides complementary information beyond cardiopulmonary measurements. Characterizing individual HHb response profiles may therefore represent a promising approach for non-invasively assessing peripheral responses and adaptations to exercise, opening new perspectives for precision exercise physiology.

O4. Assessment of fluid therapy responsiveness through hybrid diffuse optical monitoring of peripheral muscle hemodynamics in intensive care patients

Cortese L. (1), Zanoletti M. (1), Cortés E. (2), Arzola L. (1), Yaqub M.A. (1), Amendola C. (3), Buttafava M. (4), Contini D. (3,5), Gruartmoner G. (2), Lacerenza M. (4), Nogales S. (2), Oller F. (2), Torricelli A. (3,6), Durduran T. (1,7), Mesquida J. (2)

Introduction

Determination of fluid therapy responsiveness constitutes a cornerstone of hemodynamic resuscitation in critically ill patients[1]. Established approaches to this assessment rely predominantly on cardiac output (CO) quantification, typically necessitating invasive monitoring modalities, which limit their applicability[2]. In this study, we employ a novel optical platform (hDOS), combining diffuse correlation spectroscopy (DCS) and time-domain near-infrared spectroscopy (TD-NIRS) for non-invasive, real-time monitoring microvascular perfusion and oxygenation in peripheral muscle[3]. The aim is to investigate the dynamic response of both CO and peripheral microvascular parameters during a passive leg raising (PLR) maneuver, which simulates fluid administration.

Methods

Patients admitted to the intensive care unit (ICU) and subjected to a standardized PLR maneuver have been enrolled in the study. Peripheral microvascular hemodynamics of the brachioradialis muscle was continuously evaluated using the hDOS platform, yielding the microvascular blood flow index (BFI), total hemoglobin concentration (HbT), and tissue oxygen saturation (StO2). CO was quantified invasively via pulse waveform analysis through an indwelling arterial catheter. Patients were designated as fluid responders (CO responders) upon demonstration of a ≥10% increase in CO

within 60–120 seconds following PLR initiation. Relationships between CO and microvascular indices changes were examined, and the discriminative capacity of hDOS-derived parameters for identifying CO responders was assessed.

Results

A total of forty PLR maneuvers were analyzed from twenty-eight ICU patients. PLR induced a significant increase of muscle BFI, with statistically significant more pronounced responses observed in CO responders compared to non-responders (33.5% Vs. 8.6% increase in BFI). Multivariate statistical analysis identified BFI as the principal discriminating variable for CO responsiveness. Receiver operating characteristic analysis demonstrated high discriminative accuracy of non-invasively derived BFI changes for identifying fluid responsiveness (area under the curve: 0.90).

Conclusions

Non-invasive optical assessment of peripheral microvascular perfusion via diffuse optics represents a promising tool for fluid responsiveness evaluation, with the potential to enable continuous monitoring of resuscitation therapy effectiveness, reducing the dependence on invasive monitoring. Further validation studies in a larger and more heterogeneous ICU cohort are currently ongoing.

O5. Reproducibility of exercise-induced changes in tissue saturation in the gastrocnemius and vastus lateralis

Jamieson A. (1), Chawla E. (1), Li J. (1,2), Alghamdi L. (1), George A. (1), Hughes A.D. (1), Jones S. (1)

Background. Near-infrared spectroscopy (NIRS) can assess changes in tissue saturation index (TSI%) from skeletal muscle during exercise. However, limited work has compared the magnitude of TSI change and test-retest reproducibility of this simple metric between muscle groups. We hypothesised that, while the pattern of TSI change may differ between muscles, there would be inter-muscle agreement, and that reproducibility would be comparable between muscle groups.

Methods. 47 healthy adults (26 [20,31] years old; 22 (47%) female) were recruited from the staff and student population at University College London (UCL). Participants performed a maximal cardiopulmonary exercise test on a cycle ergometer while two NIRS devices (Portamon, Artinis) continuously recorded TSI from the vastus lateralis (VL) and gastrocnemius (GN) muscles. The change in TSI (ΔTSI; maximum-minimum) was calculated for each muscle. The protocol was repeated one week later (visit 2). Agreement between VL and GN ΔTSI was assessed using a hierarchical mixed-effects model, with Lin's concordance correlation coefficient (CCC), mean bias and 95% limits of agreement (LoA). Test-retest reproducibility between visits was assessed using intraclass correlation coefficients (ICC), mean bias and 95% LoA. The coefficient of variation (CV) and repeatability coefficient (RC) were also calculated.

Results. Agreement between muscle groups was low (CCC=0.28, 95% CI -0.02, 0.58). Larger ΔTSI was observed in the VL compared to the GN (mean bias 4.66% (95% CI 3.32, 6.38) with wide LoA (-6.88, 16.21%). Test-retest reproducibility across visits was low to moderate (ICC=0.39, 95% CI 0.06, 0.72). Mean bias between visits was close to nil (0.53%), but large variability was observed with wide LoA (-11.02, 12.07%), a RC of 11.55% and CV of 38.27%.

Conclusions. Exercise-induced changes in TSI were greater in the VL compared with the GN, with low inter-muscle agreement. Test-retest reproducibility was limited, with within-subject variability observed despite minimal systematic bias. These results indicate between-visit variability in exercise-induced ΔTSI in both the VL and GN.

O6. Microvascular vasodilatory capacity is impaired following 10 days of bed rest in older adults with and without metabolic impairment

Jones S. (1), Ramos S.V. (2), Hughes A.D. (1), Goodpaster B.H. (2), Coen P.M. (2)

Introduction: Periods of inactivity can have catastrophic consequences for physical function in older adults.(1) The aim of this work is to assess how microvascular vasodilatory capacity in skeletal muscle changes across 10 days of bed rest in older adults and to assess whether this change differs in the presence of pre-existing metabolic impairment such as type-2 Diabetes Mellitus (T2DM) or pre-T2DM compared to metabolically healthy individuals.

Methods: Older adults with T2DM/pre-T2DM (MET) or who were metabolically healthy (CON) completed 10 days of horizontal bed rest. Microvascular vasodilatory capacity was assessed using near infrared spectroscopy (NIRS, Moxy Monitor) to capture the post-occlusive reactive hyperaemia (PORH) in the tibialis anterior (TA) and gastrocnemius (GN) muscles following a 5-minute cuff-induced arterial occlusion. Time to 95% PORH and the rate of PORH recovery were calculated from the tissue oxygenation signal. Measurements were performed pre-bed rest and days 1, 3, 5 and 10 of bed rest. Linear mixed-effects models were used to determine the effect of time on PORH and a random intercept for

participant included to account for repeated measures. An interaction term for metabolic status was included. Where interactions were observed, time effects were stratified by metabolic status.

Results: In total, 21 participants (52% men, 58% MET, age 64[63, 67]) completed bed rest. In the TA, time to 95% PORH increased (0.40(0.08,0.73) seconds/day, p=0.014) and the rate of PORH response decreased across bed rest in all participants (-0.07(-0.140, -0.003) %/second/day, p=0.042). In the GN, similar trends were observed, but there was evidence of a greater increase in time to 95% PORH in the metabolically impaired, compared to healthy group (MET: 1.23(0.84,1.61) seconds/day, p<0.001; CON: 0.38(-0.03,0.79) seconds/day, p=0.070; p-interaction=0.006) and evidence of a greater decrease in the rate of PORH recovery in MET compared to CON (MET: -0.12(-0.18,-0.06) %/second/day, p<0.001; CON: 0.02(-0.06,0.09) %/second/day, p=0.622; p-interaction=0.007)

Conclusion: These data show that muscle microvascular vasodilatory capacity of older adults is reduced following 10 days of bed rest, an effect that appears to be greater in the GN of individuals with a pre-existing metabolic impairment.

O7. Near infrared spectroscopy-derived muscle (de)oxygenation thresholds as estimates of the maximal metabolic steady state in competitive male cyclists.

Lehtonen E. (1)(2), Knuts M. (3), Mikkonen R. (3), Gagnon D (1)(2)(4)(5)

Background. Identifying the work rate associated with the heavy-to-severe exercise domain (maximal metabolic steady state [MMSS]) boundary non-invasively is of practical value, yet the validity of near-infrared spectroscopy (NIRS)-derived thresholds against a rigorous criterion remains incompletely established.

Purpose. We hypothesized that NIRS-derived thresholds from incremental and constant-load protocols would provide valid estimates of MMSS.

Methods. Eleven Tier 3 male cyclists ($\dot{V}O_2max$ 62 ± 3 ml/kg/min) completed a step-ramp-step (SRS) protocol (1) (30 W/min), a 10-min incremental step test (ST; 25 – 30W increments) and five constant work rate (CW) trials of up to 30 min. Deoxygenated hemo- and myoglobin [HHb] breakpoints were identified by segmental linear regression from both SRS ([HHb]BP-SRS) and ST trials ([HHb]BP-ST). [HHb]BP-SRS was corrected for the lagged $\dot{V}O_2$ response with the SRS protocol. [HHb]BP-ST was determined by plotting [HHb] against work rate using the last 1 min of each step. Tissue O_2 saturation index slope (ΔStO_2) was determined from the ST (last 5 min per stage) and CW (min 10 – 30) for each work rate respectively and the work rate corresponding to $\Delta StO_2 = 0$ was identified with linear regression for both ST (ΔStO_2-ST) and CW (ΔStO_2-CW) trials separately. All NIRS-derived thresholds were assessed against MMSS defined with the modified criterion of Ozkaya et al. (2) by linear regression and Bland-Altman Analysis. SRS-derived respiratory compensation point (RCP) and $\dot{V}O_2max$ were used as reference comparators.

Results. Uncorrected ramp [HHb]BP (n = 11; 362 ± 53 W) overestimated MMSS (n = 11; 310 ± 47 W) by 53 W (LoA -11 to 116 W; r2 = 0.63). The mean SRS correction was 52 ± 12W. [HHb]BP-SRS (n = 11; 311 ± 57 W) showed negligible bias (+1 W) but LoA remained wide (-74 to 77 W; r2 = 0.55). [HHb]BP-ST (n = 8; 273 ± 54 W) underestimated MMSS by 30 W (LoA -90 to 29 W; r2 = 0.68). ΔStO_2-ST (n = 9; 287 ± 38 W) underestimated MMSS by 27 W (LoA -74 to 19 W; r2 = 0.81). ΔStO_2-CW (n = 10; 298 ± 53 W) underestimated MMSS by 15 W (LoA -67 to 38 W; r2 = 0.75). Variation in MMSS was better explained by $\dot{V}O_2max$ (r2 = 0.78) than most NIRS-derived thresholds. RCP (n = 11; 295 ± 44 W) underestimated MMSS by 15 W (LoA -41 to 12 W; r2 = 0.92).

Conclusions. In this homogeneous well-trained sample, NIRS-derived thresholds showed moderate-to-group-level good agreement with MMSS but offer limited advantage over $\dot{V}O_2max$ for explaining between-subject variance of MMSS. No NIRS method matched the overall accuracy of RCP in determining MMSS. [HHb]BP-SRS eliminated mean bias after SRS-based correction, but practical utility is limited by its wide limits of agreement and reliance on metabolic cart data for applying the correction. ΔStO_2 methods offered the most practical standalone NIRS-based approach for MMSS estimation, showing superior precision without ancillary equipment, albeit with residual systematic underestimation of MMSS.

O8. Relationship between Ventilatory Thresholds and NIRS Breakpoints Assessed with Frequency-Domain, Time-Domain and Continuous-Wave NIRS Devices

Monot T.(1), Bochicchio G.(2), Ferrari L.(2), Millet G.Y.(1,3), Pogliaghi S.(4), Colosio A.L.(1)

We aimed to investigate the relationship between power output (PO) at systemic thresholds (i.e. the gas exchange threshold [GET] and the respiratory compensation point [RCP]) and the first and second NIRS BP (BP1 and BP2) determined using different NIRS devices. We hypothesized to find stronger correlations between PO at systemic thresholds and NIRS BP for time-domain (TD) and frequency-domain (FD) than for continuous-wave (CW) NIRS.

14 participants performed a maximal ramp incremental test with continuous measurement of gas exchanges and muscle oxygenation. Two FD (FD1 and FD2), one TD, and one CW NIRS devices were placed over the vastus lateralis muscles, with FD1 and TD on one leg and FD2 and CW on the contralateral leg. The GET and RCP were visually identified with the standard technique and subsequently translated into the corresponding PO accounting for mean response time (1). NIRS BP1 and BP2 were identified by fitting the deoxyhaemoglobin signal ([HHb] for FD and TD; Δ[HHb] for CW) plotted as a function of time with a triple-linear function and converted to PO. Pearson correlations and Bland-Altman analyses were used to assess the association and agreement between the PO at the systemic thresholds and NIRS BP, respectively.

Among the 14 tests, BP1 was found in 8, 9, 10 and 3 tests with TD, FD1, FD2 and CW, respectively, while BP2 was found in 13, 9, 11 and 6 tests. The association between GET and the BP1 could not be tested for CW due to the low number of BP1 ($n = 3$). GET was significantly associated with BP1 for TD ($r = 0.92$, $p < 0.01$) and FD1 ($r = 0.69$, $p < 0.01$) but not FD2 ($r = 0.38$, $p = 0.28$). Similarly, RCP was significantly associated with BP2 for TD ($r = 0.68$, $p < 0.05$) and CW ($r = 0.93$, $p < 0.01$) but not for FD1 ($r = 0.43$, $p = 0.25$) or FD2 ($r = 0.47$, $p = 0.14$). Bland–Altman revealed small mean biases for BP1 relative to GET (0.1–4.2 W), whereas agreement for BP2 relative to RCP was more variable across devices, with mean biases ranging from −23.4 to 18.1 W and wide limits of agreement.

We found strong associations between GET and BP1 for TD and FD1, and between RCP and BP2 for TD and CW. Only TD identified both BP1 and BP2 associated with the corresponding systemic thresholds, suggesting that its methodological characteristics may facilitate the identification of physiologically relevant muscle oxygenation breakpoints. Agreement was better for BP1 than BP2.

O9. Age- and Sex-Related Differences in Skeletal Muscle Oxygenation and Microvascular Perfusion Revealed by Combined TD NIRS and DCS

Nabacino M. (1), Amendola C. (1), Contini L. (1), Contini D. (1, 3), Spinelli L. (2), Torricelli A. (1, 2), Lauretani F. (4), Porcelli S. (5), Brusco C. M. (6), Franchi M. V. (6), Re R. (1, 2)

Objective: To assess age- and sex-related differences in muscle oxygenation and microvascular perfusion in untrained middle-aged (MA) and older (OLD) adults using Time-Domain Near-Infrared Spectroscopy (TD NIRS) and Diffuse Correlation Spectroscopy (DCS).

Hypothesis: Aging is associated with declines in muscle mass and power [1], which may be reflected in alterations of TD-NIRS- and DCS-derived biomarkers of muscle oxygenation and perfusion.

Methods: Eighty-eight untrained participants were enrolled, including 53 MA (58.4 ± 3.0 years, 60% female) and 35 OLD (76.9 ± 4.4 years, 37% female). Participants underwent a vascular occlusion test of the right femoral artery. Regional muscle oxygen saturation (rSmO2) was continuously measured by TD NIRS throughout the protocol, while DCS monitored the blood flow index (BFI) [2]. TD NIRS data were analyzed assuming a two-layer geometry (adipose tissue, whose thickness was measured by ultrasound, and muscle), while DCS data analysis assumed a homogeneous medium. The rSmO2 desaturation slope during occlusion (slope 1) was calculated between 30 s and 90 s after occlusion onset, whereas the reperfusion slope (slope 2) was calculated during the first 10 s after occlusion release. Additionally, the area under the curve (AUC) of both $rSmO_2$ and BFI during post-occlusion recovery was quantified.

Results: Age- and sex-related physiological differences were reflected in both TD-NIRS- and DCS-derived biomarkers. Among women, rSmO2 slope 1 was steeper in the MA group than in the OLD group ($p=0.015$), suggesting higher resting muscle oxygen extraction capacity. No corresponding age-related differences were observed in men, nor were there significant sex differences within age-matched groups. Neither rSmO2 slope 2 nor rSmO2 AUC differed significantly by age or sex, indicating comparable reperfusion dynamics and oxygen recovery across groups. Conversely, BFI AUC showed a significant age-related decline in women ($p=0.03$), but not in men. Furthermore, sex differences in BFI AUC were observed only within the OLD cohort ($p=0.007$), suggesting a greater age-associated reduction in lower-limb microvascular perfusion in women than in men.

Conclusions: The combined use of TD NIRS and DCS provides a non-invasive approach for detecting age- and sex-related differences in muscle oxygenation, reperfusion dynamics, and microvascular function. These findings suggest that aging may differentially affect skeletal muscle physiology in women and men, particularly with respect to microvascular perfusion.

Poster Presentations

1. Technical & Methodological Validation

P1. Test-retest reliability of continuous wave, frequency-domain, and time-domain NIRS for assessing muscle oxygenation during constant load cycling

Gianluca Bochicchio(1), Luca Ferrari(1), Thomas Monot(2), Guillaume Millet(2), Alessandro Colosio(2), Silvia Pogliaghi(3)

Background: the ability of skeletal muscle to receive and utilize oxygen is a key determinant of peripheral adaptations to training. Different near-infrared spectroscopy (NIRS) systems, including continuous-wave (CW), frequency-domain (FD), and time-domain (TD) technologies, assess real-time changes in muscle oxygenation (TSI%). However, different physical principles, modelling assumptions, and analytical procedures may affect the reliability of the derived parameters. The aim of the present study was to investigate the reliability of three different NIRS devices, during constant-load cycling exercise.

Methods: fourteen individuals (6 women, 26.0 ± 4 .3 yrs) performed a moderate-intensity, constant-load cycling trial in two sessions. NIRS probes were placed over the vastus lateralis muscles of both legs. TSI% was simultaneously recorded at 1 Hz, time-aligned to exercise onset, and fitted over the first 120 s with a mono-exponential function to derive baseline, steady-state, amplitude, and tau outcomes. Test-retest differences between sessions were assessed using paired t-tests. Relative reliability was quantified using ICC(A,1) while absolute reliability was quantified using the coefficient of variation (CV%), bias, and minimal detectable change (MDC).

Results: paired comparisons revealed no significant differences between sessions for any outcomes and device. However, reliability indices differed across devices and outcomes. FD and TD showed moderate-to-excellent relative reliability for steady-state and amplitude outcomes. Absolute reliability was also better for FD and TD, with low CV% values (0.73 – 2.87%), small bias (0.07 – 0.58 TSI%), and MDC values (1.79 to 6.85 TSI%) for baseline and steady-state outcomes. Conversely, CW showed poorer relative (ICC: 0.298 – 0.551) and absolute (CV%: 12 - 414) reliability across outcomes.

Conclusion: test-retest reliability of TSI% responses during constant load cycling was device- and outcome-dependent. FD and TD technologies provided more reliable TSI-derived measurements than CW, particularly for baseline and steady-state outcomes, whereas kinetic parameters showed limited reliability. These findings suggest that FD and TD NIRS may be more suitable for longitudinal assessment of TSI% during exercise, while caution is required when interpreting CW-derived changes over time.

P2. Effect of adipose tissue thickness correction method and short channel regression on muscle oxygenation classification: a preliminary study

Borot L. (1,2), Vidal Q. (1), Devaux Y. (1), Duchemin H. (1), Bosc J. (1), Belda G. (3), Nicolas B. (3), Pla S. (1), Jean P. (1), Perrey S. (1), Dray G. (1), Vergotte G. (1)

Muscle near-infrared spectroscopy (mNIRS) signals are well known to be influenced by the adipose tissue thickness of muscles investigated. While most of commercial systems use a fixed differential pathlength factor (DPF) or allow the user to set a specific DPF for the whole device (with no wavelength distinction nor inter-optode distances), new approaches based on results previously published using time domain mNIRS could allow the DPF to be adapted for each participant and muscle (Pirovano et al., 2020). In this study, we used machine learning classification approaches, to quantify the effect of different methods to correct for ATT. We used two datasets that involve isometric and concentric / eccentric contractions of vastus lateralis at different intensities of exercise (20%, 40% and 60% of maximal voluntary contraction for isometric contractions, and 30% and 50% for eccentric and concentric contractions). Continuous wave mNIRS system (Oxyon, Semaxone, FR) was used in this study. This system comprised several dual-wavelength channels with different inter-optode distances (4 channels at 35mm, two channels at 18mm and one at 10mm) that allow to implement the different ATT correction methods, as well as short-channel regression, in our pipeline. ATT measurements were obtained using a skin fold caliper at the start of each experiment, on the site bellow the mNIRS measurement point. We extracted the area under the curve for oxy[heme] and deoxy[heme] from the mNIRS signals using different processing pipelines, some of which were performed with and some without short channel regression, with a fixed DPF (=4) without considering ATT of the participant, with a DPF (=4) using ATT as a feature for classification and with an individual DPF calculation based on ATT for each inter-optode distances and wavelength (750 and 850nm). Our preliminary results are mixed and depict the effects of both the ATT method used and short channel regression. Future studies combining time domain mNIRS at multiple wavelengths, inter-optode distances with ATT measurements and multiple muscle sites would allow to better understand the importance of considering ATT in future analysis pipelines. Furthermore, investigating DPF changes during voluntary contractions at different intensities and contraction modes will be necessary.

P3. Effect of different contractions modes on NIRS-based muscle oxygenation

Devaux Y. (1), Borot L. (1,2), Vergotte G. (1), Belda G. (3), Nicolas B. (3), Pla S. (1), Jean P. (1), Vidal Q. (1), Dray G. (1), Perrey S. (1)

In our daily activities, for example during walking, running or cycling, we use different modes of muscle actions. The two most common are the eccentric (Ecc) and concentric (Conc) actions. Ecc actions, where the muscle lengthens while being active, have been shown to differ from Conc actions, where the muscle shortens while being active, in several aspects. Previous studies have shown differences in rate of perceived exertion, EMG activity and cortical activity between Ecc and Conc actions at the same mechanical output (Borot et al., 2024). However, it remains unclear how muscle oxygenation pattern differs between the two modes, especially when the intensity is defined at the same percentage of maximal voluntary contractions in each modality. The aim of this study was then to investigate changes in oxy[heme], deoxy[heme] and total[heme] in Ecc and Conc actions of vastus lateralis at 30% and 50% of maximal voluntary contraction, using CW near infrared spectroscopy at 60°/s on an isokinetic dynamometer. Twenty-one participants took part in this study. The maximal voluntary contraction was extracted for each action mode independently. The task involved 3 trials of 10 contractions in each modality. A continuous wave mNIRS system (Oxyon, multichannel system, sampling rate 100Hz, Semaxone, FR) was used. Rate of perceived exertion was evaluated after each trial using CR100 Borg scale. We then extracted the area under the curve of each chromophore from the data. Linear mixed models were then used to highlight differences between the two action modes at different exercise intensities. Our results suggest differences in torque production as well as difference in oxygenation variables between the two exercise modes and intensities. For deoxy[heme]), there was a significant main effect of intensity, but the main effect of contraction mode was not significant. A significant contraction-by-intensity interaction was observed. However, only an intensity effect was observed for oxy[heme] and total[heme]. Furthermore, the rate of perceived exertion indicated a significant intensity effect. These first results could help to better understand the impact of contraction mode in rehabilitation and training.

P4. Validation of a new multichannel continuous wave muscle NIRS device

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We present a new, portable, multichannel muscular near-infrared spectroscopy (mNIRS) device developed by Semaxone company. This continuous wave mNIRS system includes seven multi-distance, dual-wavelength channels (4 long channels: 35mm; 2 mid-distance channels: 18mm and one short-distance channel: 10mm, at two wavelengths: 750-850nm; sampling frequency: 100Hz). The aim of this study was to validate this new device in vitro and in vivo (Barstow, 2019). We are presenting here the in vivo validation results obtained via a test-retest experimental design involving isometric contractions of the quadriceps muscle group at three intensity levels (20, 40 and 60% of maximal voluntary contraction). Two vastii muscles of the quadriceps were investigated (vastus lateralis and vastus medialis). From this data, we extracted multivariate dependant variables (mean, min, max, AUC) for oxy[heme], deoxy[heme] and total[heme]. Linear mixed models were used to highlight the capacity of the two devices (Oxyon Semaxone vs. Portamon Artinis) to discriminate significant differences between the 3 levels of intensity. Intraclass correlation coefficients (3,1) was also calculated from the mixed models output to evaluate consistency between devices. Furthermore, a machine learning approach (random forest) was used to test the capacity of devices to classify the intensity levels. As hypothesised, our results highlighted the capacity of the two devices to discriminate changes in intensity level and classify them. However, as expected, based on previous comparisons of mNIRS devices, intraclass correlation coefficients were moderate for the different variables, and a significant bias between the devices was found. These results suggest that, while mNIRS devices are both able to discriminate conditions, the output value is influenced by the hardware design. Considering these results, our experiment validates the new Semaxone mNIRS device as a valuable system for addressing future scientific questions.

P5. Comparative Performance of Continuous Wave and Time-Domain NIRS to Frequency-Domain NIRS in Assessing Muscle Oxygenation Kinetics During Cycling.

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Background: Affordable continuous-wave (CW) devices and innovative time-domain (TD) near-infrared spectroscopy (NIRS) systems offer viable alternatives to the more expensive frequency-domain (FD) technology for the characterization of muscle oxidative metabolism. Yet, the validity of muscle oxygenation indexes across instruments still requires a direct, concurrent verification. We tested the validity of CW and TD compared with a FD device in the characterization of muscle oxygenation during cycling.

Methods: Fourteen youngs (6 F) performed 2 repetitions of an identical moderate-intensity, constant-load cycling trial with a 10-min recovery, repeated after 7 days. NIRS devices were placed on the vastus lateralis: one FD probe paired with the TD, the other FD probe paired with the CW. Muscle oxygenation (TSI%) was recorded simultaneously by each device, time-aligned for exercise onset, fitted with a monoexponential function up to 120 s to calculate baseline, amplitude, and tau. The agreement between parameters of the 4 repetitions derived from TD and CW was compared against the ipsilateral FD device using separate linear mixed models (device × trial × day), Bland-Altman analysis, and Lin's concordance correlation coefficient (CCC).

Results: A significant main effect of device was shown for FD vs TD ($p<0.001$) but not for FD vs CW ($p=0.713$), with no effect of session or interactions for baseline and amplitude across devices. No main effect was detected for tau values for all comparisons. For FD vs TD, a significant systematic bias was found for baseline (4.94%, $p=0.002$) and amplitude(3.26, $p<0.001$), yet not for tau values. For FD vs CW, a significant bias was detected for amplitude values only (-9.06, $P=0.006$). Poor concordance correlation coefficients (from 0.022 to 0.497) were observed across devices, with a significant proportional bias for baseline (1.40%, $p<0.001$) and amplitude (1.73, $p<0.001$) in FD vs CW.

Conclusion: Our results indicate that both TD and CW NIRS overestimate baseline and amplitude TSI% vs FD NIRS during constant-load cycling. The lack of significant differences between devices in the tau of the response may depend on the large variability in this parameter. From a practical perspective, different NIRS devices cannot be used interchangeably to assess skeletal muscle oxygenation kinetics.

P6. Regional Fascicle Dynamics and NIRS-derived Oxygen Consumption Kinetics in Vastus Lateralis during isometric contraction

Gasparini, A.1, Trinchi, M.1, Latini, D.1 Monte, A.1, Zamparo, P.1, Tam, E.1

The aim of this study was to determine whether regional differences in vastus lateralis (VL) fascicle behaviour, previously observed during isokinetic contractions1, persist during intermittent isometric exercise and whether these regional variations are coupled with differences in local muscle oxygen consumption (mV'O2) kinetics.

Hypothesis: We hypothesized that the distal VL would show greater fascicle velocity and, consequently, higher local metabolic rate than the proximal region.

Methods: Thirteen males completed a session on a custom isometric chair. NIRS optodes and ultrasound probes were placed over the proximal (50%) and distal (75%) VL landmarks. A proximal thigh cuff enabled rapid arterial occlusions, while a metabolimeter mask tracked global metabolic data. Following baseline and warm-up, participants completed two 5s MVCs and then a 4 min intermittent isometric exercise (1s/1s contraction at 25% MVC) followed by 5 min of occlusions (5s occlusion/10s recovery) to calculate regional mV'O2 recovery kinetics2.

Results: Contrary to the hypothesis, VL fascicle velocity did not differ regionally during isometric contractions (-0.76±1.45 vs -0.65±0.99 cm/s, $p=0.85$). Hbdiff kinetics showed no regional differences for either the time constant (Tau) (25.6±6.44 vs 27.6±10.83 s, $p=0.91$) or amplitude (1.66±0.72 vs 1.56±0.60 %/s, $p=0.91$). However, tissue saturation index (TSI) was significantly higher proximally than distally at rest (69.58±4.82 vs 53.42±5.06 %, $p<0.05$) and at the end of exercise (66.08±4.89 vs 50.40±4.98 %, $p<0.05$). Hbdiff Y intercept (Y0Hbdiff) was also greater in the proximal region (2.28±0.69 vs 1.65±0.63 %/s, $p=0.006$).

Conclusions: Unlike dynamic contractions, intermittent isometric exercise did not elicit regional differences in VL fascicle velocity or mV'O2 recovery kinetics. These findings suggest that regional architectural heterogeneity does not alter intrinsic metabolic recovery profiles under static conditions. Nevertheless, the significantly higher proximal TSI (%) and Y0Hbdiff indicate region-specific differences in oxygenation and local O2 availability that appear partly independent of mechanical behaviour.

P7. High-Density-NIRS Reveals a Depth-Dependent Gradient in Intramuscular Oxygenation During Incremental Exercise

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Background/Objective: Different regions of the same skeletal muscle can vary in fibre-type composition, metabolism and recruitment [1]. High-Density-NIRS (HD-NIRS) records oxygenated and deoxygenated haemoglobin (HbO & HbR, respectively) using many source-detector (SD) distances simultaneously, providing signals across different depths and locations within a muscle. We tested whether HD-NIRS can detect within-muscle heterogeneity in HbO and HbR responses to incremental cycling in the vastus lateralis (VL).

Methods: Healthy participants were recruited to complete an incrementally loaded cardiopulmonary exercise test (CPET). An HD-NIRS device with 108 channels (LUMO, Gowerlabs [2]) was positioned over the VL and recorded at 12.5Hz continuously throughout rest and exercise. Channels were grouped into six regions by recording depth (shallow/mid/deep, 0-20/20-35/35-60 mm) and position (distal/proximal). Peak HbO/HbR (mean over final 30 s of exercise vs resting baseline) were computed per region per session. Repeated-measures ANOVA (Region, 6 levels; Bonferroni post-hoc, 15 pairs) tested regional HbO and HbR differences.

Results: HbO showed a strong depth main effect ($F(2,44)=140.9$, $p<0.0001$; Figure 1): shallow regions increased (+4.6±1.1 to +5.1±1.2 μM), deep regions decreased (−2.2±1.0 to −2.0±1.3 μM), with mid region near zero; all depth pairs significant (Bonferroni $p<0.0001$). Position main effect ($p=0.47$) and Depth×Position interaction ($p=0.67$) were non-significant, confirming a consistent depth gradient regardless of position. HbR showed no depth effect ($p=0.56$) and no interaction ($p=0.35$); a marginal position effect was noted ($F(1,22)=4.56$, $p=0.044$; Proximal>Distal).

Conclusion: HD-NIRS revealed within-muscle heterogeneity in HbO across increasing depths. There was no difference in distal versus proximal regions and the pattern of difference across depths was similar in the proximal and distal portions of the muscle. HbR showed little depth variation. HbO increasing superficially but decreasing at depth may partly reflect greater adipose/skin contribution superficially and depth-dependent fibre-type composition within VL.

P8. Tibial Skeletal Muscle Absorption Spectra Analysis through novel Time-Domain Near Infrared Spectroscopy Device

Pesenti S.(1), Spinelli L.(2), Torricelli A.(1,2), Re R.(1,2)

Introduction

Time Domain – Near Infrared Spectroscopy (TD-NIRS) allows for the non-invasive assessment of the oxidative metabolism and composition of skeletal muscle [1]. The main advantage of TD-NIRS over other NIRS modalities like continuous wave (CW) NIRS is its capability of reliably retrieving absolute values for the concentration of tissue components and an increased depth selectivity. Recent technological advances in TD-NIRS have focused on the addition and parallelization of multiple wavelengths. Multi-wavelength systems in fact allow for a better estimation of tissue composition and the retrieval of multiple biological markers such as oxygenated and deoxygenated hemoglobin (O2Hb, HHb), water, lipids, cytochrome c-oxidase, and collagen.

Methods

A novel dual distance TD-NIRS device capable of both serial and parallel acquisition for static (i.e., at rest) and dynamic measurements (i.e., during physical exercise and/or vascular occlusion test) has been designed and built. The system allows serial measurements in the spectral range from 600 to 1100 nm or parallel measurements at eight wavelengths: 690, 730, 810, 830, 890, 930, 980, and 1050 nm. A full characterization of the developed instrument has been performed at different wavelengths, according to the MEDPHOT and BIP protocols [2,3]: established procedures for assessing the performances of diffuse optics devices. To validate its in-vivo capabilities we present a set of static and dynamic measurements.

Results

The absorption spectra of the Tibialis Anterior was taken from 5 subjects at rest sampled between 660-1100 nm, at 1 nm step. Then comparing the tissue's composition estimated with a homogeneous model by utilizing the entire spectrum with what can be retrieved with four, and eight wavelengths.

The variation of H-/O2- Hb and Skeletal Muscle Tissue Saturation (SmO2) during a body weight tibial raise protocol where after a 30 second baseline measurement the subjects cycled between ten seconds of muscle contraction and five seconds of rest, for five minutes.

Conclusion

This work presents the full characterization and capabilities of a TD-NIRS device capable of both serial and parallel acquisition at two inter-fiber distances with both standard and in-vivo protocols. With acquisition times compatible with both static and dynamic measurements.

P9. Time-Resolved Diffuse Correlation Spectroscopy Using a Custom-Configured Ti:Sapphire Laser for Enhanced Depth Sensitivity

Saeed Samaei (1,2), Daniel Milej (1,2,3), Mamadou Diop (1,2), and Keith St Lawrence (1,2)

There is a clinical need for non-invasive, bedside technologies for measuring tissue perfusion. Diffuse correlation spectroscopy (DCS) is a promising optical method [1]; however, conventional continuous-wave (CW) DCS measurements are heavily weighted to superficial tissues, which can be an issue when assessing cerebral blood flow or muscle blood flow, depending on the thickness of the adipose layer. Time-resolved DCS (trDCS) improves depth selectivity by using the time-of-flight (TOF) of photons to resolve different path lengths through tissue [2,3]. By selecting photons within defined temporal gates, trDCS enhances the sensitivity to blood flow in deeper layers. The challenge with this method is the requirement for a pulsed light source with sufficiently long coherence length; a combination that is not available with off-the-shelf near-infrared lasers [4,5].

We utilized a Ti:Sapphire laser (Tsunami, Spectra-Physics) custom-designed for trDCS. The laser generates picosecond pulses with an extended coherence length to enable measurements at larger source-detector separations (SDS). It was tuned to 800 nm at a repetition rate of 80 MHz. The laser output was delivered to the sample using a Graded-Index optical fiber (50¬µm core diameter, GIF50C, Thorlabs), and diffusely reflected photons were detected at an SDS of 3 cm. A single-mode fiber was used to guide photons from the sample surface to a single-photon avalanche diode detector (Micro Photon Devices) coupled to a time-correlated single-photon counting module (HydraHarp 400, PicoQuant) to generate the TOF of detected photons. To validate the capability of the system to capture DCS signals from late-arriving photons, we performed measurements on a tissue-mimicking homogeneous liquid phantom. Fig. 1(A) shows a typical TOF distribution. A 100-ps time gate was applied to select early and late photons. Autocorrelation functions were computed for each time gate [Fig. 1(B)] to assess signal quality and photon coherence. The coherence factor, β, for a series of gated signals is shown in Fig. 1(C).

Previous studies have shown that β decreases rapidly for late-arriving photons [4], restricting trDCS to short SDS (typically 1-1.5 cm). In contrast, our laser provided stable and high β values across the TOF [Fig. 1(C)]. This enabled the SDS to be increased to 3 cm and still collect DCS signals from late-arriving photons. This feature improves depth sensitivity and signal-to-noise ratio. The next step is to evaluate the system's ability to monitor blood flow in the muscle and brain.

P10. Not all breakpoints are created equally: test-retest reliability and bilateral differences of SmO_2 breakpoints during continuous cycling step tests

Skotzke P. (1,2), Meyer, T. (2), Sacchetti, M. (1)

Numerous methods exist to identify muscle oxygen saturation (SmO_2) breakpoints (BPs) to complement whole-body exercise thresholds [1], but their test-retest reliability remains largely unexplored. This exploratory analysis (a) compares test-retest reliability of different BP detection methods and (b) examines whether the power output at the BPs differs between the dominant (DOM) and non-dominant (NDOM) leg and averaged SmO_2 (AVG). We hypothesized that reliability would differ meaningfully across methods, but no differences exist between sides.

A data set of 36 (n = 12 males, 3 tests each) continuous cycling step tests (start 1 W/kg, increase 0.5 W/kg every 5 min) was analysed with SmO_2 measured at the vastus lateralis. Twelve methods were applied across BP1 (8 variants) and BP2 (10 variants): visual identification; double-segmented regression on raw SmO_2, stage-mean SmO_2, stage slope, and the power/SmO_2 ratio (both BPs); log-log regression on stage-mean SmO_2 and the power/SmO_2 ratio (BP1 only); Dmax and modDmax on stage-mean SMO_2 and the power/SmO_2 ratio (BP2 only); and the inflections of the 2nd derivative of a 4th-degree polynomial (both BPs).

The SmO_2 slope and poly methods failed to identify the BP in more than 33% of cases and are excluded. Thus, 15 of 18 method×BP variants are reported. The ICC(2,1) ranged from 0.25 – 0.87, CV from 3.3 – 22.0 % and SEM from 9 – 51 W. Pairwise bootstrapped comparisons revealed significant differences in test-retest reliability between ~17 % of methods when expressed as within-subject SD and 19 % when expressed as CV ($p < 0.05$). 8 % of the comparisons between DOM, NDOM and AVG yielded significantly different power outputs ($p < 0.05$). The log-log method on the power/SmO_2 ratio of AVG was most reliable for BP1 (ICC 0.81, CV 8.3 %, SEM 17 W) and the visual identification most reliable for BP2 (ICC 0.83, CV 5.8 %, SEM 17 W).

Test-retest reliability varied substantially between BP methods, with the best-performing methods not reaching typical reliability of whole-body thresholds. Visual identification may be the most reliable, but precision is limited by the protocol. Practitioners need to understand the uncertainty of methods when interpreting longitudinal data from NIRS. No clear systematic side differences emerged, suggesting single-probe measurement may suffice.

P11. Comparison of tissue oxygen saturation measurements across commonly used near-infrared spectroscopy devices using tissue-mimicking phantoms

Vandenhaute S. (1), Forrer T. (2, 3), Baláš J. (1)

Purpose: Near-infrared spectroscopy (NIRS) has been increasingly used in sports science and training applications to assess tissue oxygen saturation (StO2), with several devices available (1). Although pairwise comparisons have been investigated (2), a comprehensive evaluation of StO2 measurements across multiple devices remains lacking. The aim of this study was to compare StO2 measurements obtained from commonly used NIRS devices using tissue-mimicking phantoms. We hypothesized that the mean StO2 would differ between devices, while reliability would be high within each device.

Methods: Five NIRS devices (Artinis PortaMon and PortaLite, Moxy Oxygen Monitor, Train.Red FYER, and ISS OxiplexTS) were tested 12 times on two tissue-mimicking phantoms with differing scattering and absorption coefficients, with each trial lasting 3 minutes. Mean trial StO2, values were analyzed using a linear mixed model with device, phantom, and their interaction as fixed effects and trial as a random effect. Reliability across 12 trials was assessed using the coefficient of variation (CV) and the standard error of measurement (SEM). Sensitivity was defined as the mean difference between the two phantom conditions.

Results: A very large effect of device on mean StO2 was observed ($\eta p^2 = 0.88$; $p < 0.001$). Mean StO2 did not differ between OxiplexTS and FYER. However, compared to OxiplexTS, most devices underestimated StO2 values: Moxy by 21.3% ($p < 0.001$), PortaMon by 5.4% ($p < 0.001$), and PortaLite by 2.4% ($p = 0.002$). A significant device x phantom interaction was observed ($p < 0.001$), indicating differences in sensitivity to phantom optical properties. Moxy showed the largest sensitivity ($\Delta = 13.4\%$; $p < 0.001$), followed by OxiplexTS ($\Delta = 7.6\%$; $p < 0.001$) and PortaLite ($\Delta = 2.3\%$; $p = 0.002$), whereas PortaMon and FYER did not detect significant differences between the phantoms. Reliability varied across devices, with FYER showing the lowest variability (CV = 0.010; SEM = 0.6%), followed by PortaMon (CV = 0.023; SEM = 1.3%), OxiplexTS (CV = 0.026; SEM = 1.5%), Moxy (CV = 0.045; SEM = 1.4%), and PortaLite (CV = 0.050; SEM = 3.0%).

Conclusion: NIRS devices are not interchangeable, as substantial differences were observed in StO_2 values, sensitivity, and reliability. These findings highlight a trade-off between sensitivity and reliability, indicating that device-specific characteristics should be considered when interpreting and comparing outcomes, particularly across studies. The present phantom-based findings form part of a broader evaluation that also includes vascular occlusion testing in human participants, thereby extending the relevance and applicability of the results.

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2. Exercise Physiology & Sport-Specific Performance

P12. Interaction of muscle oxygen saturation with physiological and psychological parameters during cycling in the heavy and severe intensity domains

Barbieri RA., Vegharíasl B., Rahimzadeh M., Marcora SM.

Near-infrared spectroscopy (NIRS) for measuring muscle oxygen saturation (SmO_2) is increasingly popular for monitoring cyclists' training. Understanding how SmO_2 interacts with physiological and psychological parameters in the heavy and severe intensity domains is relevant for training monitoring. This study aimed to assess these parameters during cycling at different intensities within these domains, examine their interaction with SmO_2, and verify their reproducibility across days. Seven male amateur cyclists participated in the study (41.0 ± 11.2 yrs; 76.5 ± 9.9 kg; 176.6 ± 8.0 cm; VO_2max 45.50 ± 5.92 $mL \cdot kg^{-1} \cdot min^{-1}$ at 297.1 ± 53.4 W). First, they performed an incremental test to determine the ventilatory thresholds (VT1 and VT2) and define the intensity domains. They then completed four 3-min exercise bouts, in random order, over two days (two bouts per day, with at least 30 min of recovery between them). Intensities ranged from VT1 + 25 W (A) to 105% of VT2 (D), with intermediate points B and C. A, B, and C corresponded to the heavy domain and D to the severe domain. During each bout, SmO_2, blood lactate (Lac), heart rate (HR), and rating of perceived exertion (RPE) were monitored. One week later, the protocol was repeated to verify reproducibility. SmO_2 differed significantly only between the lowest (A) and highest (D) intensities (A = 51.4 ± 21.0%; D = 28.5 ± 12.8%; $p = 0.019$). For lactate, intensity A was significantly lower than C and D (A = 2.4 ± 1.0; C = 4.0 ± 1.2; D = 5.4 ± 2.3 $mmol \cdot L^{-1}$; $p = 0.001$), and C was significantly lower than D ($p = 0.035$). An effect of intensity was observed for HR and RPE ($p = 0.001$), with significant differences between intensities. Intraclass correlations between measurements on different days were significant (SmO_2: 0.636; Lac: 0.897; HR: 0.906; RPE: 0.768; $p < 0.05$), with no statistical difference between days, confirming reproducibility. SmO_2 interacted with the physiological and psychological parameters and showed acceptable reproducibility across days during exercise in different intensity domains. However, no significant differences in SmO_2 were found among efforts within the same heavy domain (A, B, and C), with a significant difference observed only between heavy and severe domains (A vs D), indicating that SmO_2 may be more sensitive to changes in intensity domain than to load variations within a domain.

P13. Finger Force Generation Mechanisms in Rock Climbing During an All-out Task

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Objective: To evaluate finger force generation mechanisms in rock climbing during an all-out task and determine how neuromuscular activity (electromyography, EMG) and tissue oxygenation (near-infrared spectroscopy, NIRS) relate to fingertip force in advanced climbers versus healthy controls.

Hypothesis: We hypothesized that force output is primarily driven by EMG amplitude (RMS) and mean frequency (MNF), and potentially modulated by climbing experience and sex. We adopted an exploratory modelling approach to determine whether tissue oxygen saturation (StO2) directly predicts force or is instead modulated by neuromuscular and demographic factors.

Methods: Thirty-eight participants (21 climbers, 7 female; 17 control, 7 female) performed an all-out protocol [1] of 30 consecutive repetitions (7 s press, 3 s release) on a climbing-mimicking setup for isometric finger flexion [2], targeting flexor digitorum profundus (FDP). Force was measured via strain gauge. EMG and NIRS were recorded from FDP [3]. For each repetition, the middle 5 s of contraction were used to compute mean force, EMG RMS, EMG MNF, and StO_2. Linear mixed-effects (LME) models of force and StO2 were fitted with repeated repetitions and participant-level random effects.

Results: Fig. 1 shows group means and standard errors of the mean (SEM) across measured variables. Generated force was associated with EMG RMS ($\beta = 0.47$, $p < 0.001$) and EMG MNF ($\beta = -0.0016$, $p = 0.015$). The control group ($\beta = -0.69$, $p < 0.001$) and females ($\beta = -0.39$, $p < 0.001$) showed lower force intercepts. Force declined across repetitions ($\beta = -0.018$, $p < 0.001$), with weaker EMG RMS–force coupling ($\beta = -0.013$, $p < 0.001$) and weaker EMG MNF–force coupling ($\beta = -0.00028$, $p < 0.001$) over repetitions. EMG RMS–force coupling was weaker in the control group ($\beta = -0.19$, $p < 0.001$) but stronger in females ($\beta = 0.070$, $p = 0.044$). The EMG MNF–force coupling was positive in the control group but negative in climbers (interaction $\beta = 0.0048$, $p < 0.001$). StO_2 was not associated with force, but was significantly associated with repetitions ($\beta = 0.13$, $p < 0.001$), EMG RMS ($\beta = 1.48$, $p = 0.018$), and EMG MNF ($\beta = 0.15$, $p < 0.001$).

Conclusion: Climbing-specific finger force generation is driven by neuromuscular activation and modulated by climbing experience and sex. Force declines across repetitions, and EMG–force coupling weakens, indicating reduced neuromuscular efficiency. The control group shows weaker EMG RMS–force coupling and reversed MNF–force coupling compared to climbers, suggesting different motor unit recruitment strategies. Females exhibit stronger EMG RMS–force coupling despite lower baseline force, indicating a neuromuscular strategy possibly related to activating larger number of motor units and/or involving more motor units of large size than males. StO_2 does not appear to be directly associated with force, but is modulated by neuromuscular activity.

P14. Energetic implications of underwater turn-phase duration in front crawl swimming

Bosetto P. (1), Coloretti V., Discepoli S., Fantozzi S., Cortesi M.

Introduction. Competitive swimming is characterized by start, clean swimming, and the turn phase. The turn phase substantially influences swimmers' energy expenditure and physiological responses [1]. However, the energetic and muscular effects of different underwater distances during the turn phase remain poorly understood [2].

Objective. This study aimed to characterize the energetic (energy cost (C), blood lactate (La-)) and muscular (muscle desaturation, ΔSmO_2) responses to increasing underwater distance during the turn phase performed at two different aerobic exercise intensities.

Hypothesis. We hypothesized that increasing the duration of the underwater phase (i.e., performing a greater number of underwater kicks) would increase both the C, ΔSmO_2 and La- at a given exercise intensity.

Methods. Fourteen national-level swimmers completed 10 times 300 m front crawl trials in a 25-m pool at two aerobic intensities: five trials at 78% and five trials at 86% of their mean velocity (vmean) achieved during a 400 m front crawl. At each intensity, the number of underwater kicks performed after each turn was randomized across trials from 0 to 4 kicks, thus varying the duration of the underwater phase (e.g. 5.8 vs 8.3 s at 78% and 5.2 vs 7.3 s at 86% of vmean). ΔSmO_2 was continuously monitored over the vastus lateralis using nirs (Moxy), while energetic variables were assessed using the back-extrapolation method (Cosmed, K5) [3].

Data and Results. At the same intensity, C varied significantly across the underwater kick conditions (at 0 kicks, 0.76 and 0.87 kJ/m; at 4 kicks, 0.87 and 0.99 kJ/m for 78% and 86% of vmean) ($p < 0.01$). ΔSmO_2 also differed significantly across the number of kicks (at 0 kicks, 36% and 44%; at 4 kicks, 49% and 56% for 78% and 86% of vmean) ($p < 0.01$). However,

Bonferroni post hoc analysis revealed no significant difference between the 3 and 4 kick conditions. No significant differences were observed for La- (net) across the underwater kick conditions (at 0 kicks, 0.8 and 1.9 mmol/L; at 4 kicks, 0.8 and 2.9 mmol/L for 78% and 86% of vmean) ($p = 0.063$). Furthermore, a very strong inverse correlation was observed between energy cost (C) and ΔSmO_2 ($r = -0.98$).

Conclusions. Increasing the underwater phase duration increases swimming energy cost (C) and muscle deoxygenation (ΔSmO_2), regardless of swimming velocity.

P15. When Recovery Fails: Do 30-15 Muscle Reoxygenation Dynamics Track VT2 in Elite Male Soccer Players?

Feldmann Andri. (1,2) Herzog Sven. (3) Philippi Manuel. (3) Batterson Philip (2)

This study examined whether muscle reoxygenation dynamics during the 30-15 intermittent running test are associated with second ventilatory threshold (VT2) speed in elite male soccer players. VT2 reflects a maximal sustainable running intensity during continuous exercise; above this speed, fatigue-related physiological disturbance accumulates. In intermittent exercise, brief recoveries may allow athletes to tolerate speeds above this continuous boundary by partially restoring muscle oxygenation between bouts. We hypothesized that the speed at which regional muscle oxygen saturation (rSmO2) recovery peaks begin to decline during the 30-15 test would be related to VT2 speed but would not show perfect agreement because intermittent recovery capacity represents a related but distinct physiological demand. Twenty-one elite male professional soccer players completed an incremental gas-exchange treadmill step test to determine VT2 and a field-based 30-15 intermittent running test. During both tests, a muscle near-infrared spectroscopy (mNIRS) device was worn on the left vastus lateralis. As a validation reference, the second muscle oxygenation breakpoint (BP2) during the step test was compared with gas-exchange VT2. In the 30-15 test, rSmO2 recovery maxima from each work-recovery cycle were smoothed using a 3-cycle rolling average; the recovery-derived marker was defined as the speed at which this rolling peak began to drift downward. Step-test BP2 corresponded well with VT2 speed (n=21, r=0.730, CCC=0.64), but occurred 0.50 km·h−1 below VT2 on average, with limits of agreement from −1.99 to 0.99 km·h−1. The 30-15 recovery-peak-decline marker showed a moderate association with VT2 speed (n=21, r=0.581, CCC=0.526), with a small mean bias of 0.21 km·h−1 but wide limits of agreement from −1.95 to 2.37 km·h−1. Bland-Altman analysis indicated positive proportional bias, suggesting that the 30-15 marker became increasingly higher relative to VT2 at higher threshold speeds. These findings support mNIRS-derived BP2 as a VT2-related marker during incremental running and suggest that 30-15 muscle reoxygenation dynamics provide complementary information. Rather than replacing VT2, the recovery-peak-decline marker may reflect soccer-specific intermittent recovery reserve above continuous-threshold speed.

P16. Inspiratory muscle fatigue impairs 200-m freestyle performance without altering serratus anterior, triceps or vastus lateralis oxygenation

Fernández-Jarillo I (1), García I (2)

Introduction: We examined the effects of a loaded breathing protocol (LB) in 200-m freestyle performance and muscle oxygenation (SmO2), and whether effects scale with the individual fall in maximal inspiratory pressure (ΔMIP) and peak inspiratory flow (ΔPIF). We hypothesized that LB would slow the 200-m and alter SmO2 in proportion to ΔMIP and ΔPIF.

Methods: In a randomized crossover, 25 male Tier 2–3 swimmers completed two all-out 200-m trials 2–8 days apart, in a fresh condition (FR) and after LB to task failure (11.0 ± 3.1 min; RPE 9.7 ± 0.7). MIP and PIF were measured with a POWERbreathe KH1, with ΔMIP and ΔPIF quantifying inspiratory fatigue. SmO2 was recorded with Moxy Monitor devices on serratus anterior, triceps and vastus lateralis. For each muscle, we calculated baseline SmO2, whole-200-m SmO2min and SmO2 slopes for 0–50 m and 50–200 m. Linear mixed models were fitted with mean-centred covariates and swimmer as a random intercept. For 200-m time, fixed effects were condition, ΔMIP, ΔPIF, condition × ΔMIP and condition × ΔPIF. For each SmO2 index, fixed effects were condition, muscle, condition × muscle, ΔMIP, ΔPIF, condition × ΔMIP, condition × ΔPIF and, for during-swim indices, the velocity corresponding to that SmO2 phase.

Results: LB reduced MIP and PIF (-8% and -10%; both $p \leq .009$), with marked between-swimmer variability. LB slowed the 200-m by 1.2 s (95% CI 0.33-2.07; p=.009), and the slowing was greater the larger the ΔMIP (Condition x ΔMIP p=.039) but not ΔPIF. SmO2 differed across muscles for every metric. Faster swimming was associated with a more negative SmO2 slope in both the first 50 m (p=.013) and the 50-200 m ($p<.001$), but not with SmO2min. In contrast, LB did not alter exercising SmO2: no overall, muscle-specific, or ΔMIP/ΔPIF-moderated effect, regardless of velocity adjustment. Its only effect was on pre-race baseline SmO2, rising with larger ΔMIP (Condition x ΔMIP p=.030).

Conclusions: Inspiratory muscle loading impaired 200-m freestyle performance in proportion to the induced fall in MIP. In contrast, exercising SmO2 was not directly altered by LB in any muscle, nor was it moderated by ΔMIP or ΔPIF.

SmO2 slopes were associated with the velocity of the corresponding race segment, suggesting that muscle oxygenation kinetics mainly reflected swimming workload rather than a direct effect of inspiratory loading.

P17. Impact of local ischemia-induced metabolic disturbance on performance fatigability during endurance exercise: does timing matter?

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Objective: This study aimed to investigate the impact of locomotor muscle ischemia (LMI) applied at separate segments of a 5-km cycling time trial (TT) on muscle oxygenation (SmO2) and performance fatigability. Hypothesis: Based on previous evidence indicating that power output is downregulated to preserve muscle contraction function in response to bouts of elevated muscle metabolism during self-paced endurance exercise (1,2), we hypothesized that abrupt local metabolic disturbance would reduce SmO2 and power output (PO) to evoke comparable performance fatigability compared to a control condition (SHAM), regardless of whether LMI is applied in the start (LMI-S), middle (LMI-M), or final (LMI-F) split of the TT. Methods: Ten recreationally trained male cyclists visited the laboratory on six days (two for preliminary testing), separated by at least 48 h. Bilateral pneumatic thigh cuffs were inflated to 80% of maximal arterial occlusion pressure during different segments (0–1000m, LMI-S; 2000–3000m, LMI-M; 4000–5000m, LMI-F) or kept at 20mmHg (SHAM). The PO was continuously registered. Pre- and post-TT neuromuscular function (NMF) of knee extensors was assessed via peripheral nerve stimulation (100Hz/10Hz paired stimuli and single twitches) and 5-s isometric maximal voluntary contractions with superimposed stimuli to determine voluntary activation. Right vastus lateralis SmO2 was monitored via near-infrared spectroscopy at 1 Hz. Data: Data were analyzed using linear mixed-effects models (nlme package in R). Condition, distance, and their interaction were fixed factors for PO and SmO2. Condition was set as a fixed factor for total TT time and pre- to post-changes in NMF. In all models, subjects were included as a random effect. Results: Compared to SHAM, performance significantly deteriorated in LMI-S (-16.6 s, $p=0.036$) and LMI-F (-20.3 s, $p=0.009$), but not in LMI-M ($p=0.092$). There was no effect of condition for any NMF variables ($p > 0.206$). A significant interaction was found for PO ($p<0.001$), with lower values for LMI-S at 1000m (-64.00 W, $p<0.001$), LMI-M at 3000m (-89.89 W, $p<0.001$), and LMI-F at 4500m and 5000m (-81.65 W and -138.36 W; both $p<0.001$). Conversely, SmO2 in the LMI-F condition was significantly higher than SHAM at 5000m (9.8%, $p=0.011$). Conclusions: Applying LMI compromised endurance performance by momentarily reducing power output without exacerbating neuromuscular fatigue. Contrary to our hypothesis, muscle oxygenation only differed from the control condition when severe metabolic accumulation was superimposed on the final sprint.

P18. Muscle tissue oxygenation: a proxy of adrenaline concentration in the blood?

Romanelli M. , Roatta S.

Background:

Contralateral exercise and mental calculation are known to produce dilatation in skeletal muscles, as the result of circulating adrenaline, acting through β2-adrenoceptors [1-2]. The ensuing increase in muscle blood flow is invariably associated to increased tissue oxygenation, which could thus become a proxy of adrenaline concentration. We here addressed this hypothesis by carefully investigating the time course of the near infrared spectroscopy (NIRS) variables during increased arousal by a button-press test (BPT), requiring the subject to repeatedly press a button, as fast as possible.

Methods:

Eleven healthy subjects performed the BPT for 30 s, after relaxing for 5 min. with continuous monitoring of arterial blood pressure (ABP), heart rate (HR), cardiac output (CO), alongside NIRS parameters from the triceps and soleus muscles: changes in oxygenated (O2Hb), deoxygenated (HHb) and total (tHb) hemoglobin concentration, the tissue oxygenation index (TOI) and the total hemoglobin index (THI), the latter two being based on spatially resolved spectroscopy, more specifically focusing on the deeper muscle tissue.

Results:

In the triceps, TOI sharply increased with a latency of 5~6 s peaking at 40 s (10 s after the end of the test): +3.6 ± 2.9%, then slowly (> 90 s) decreasing towards baseline. This was accompanied by an increase in O2Hb and a decrease HHb. Similar time courses were observed in the soleus but with changes of smaller magnitude (TOI: +1.5 ± 1.4%). Interestingly, tHb and THI exhibited an increase in the forearm (THI: +5% at 30 s) while they tended to decrease in the soleus (THI: -1.0% at 40 s).

Both HR and ABP sharply increased with lower latency (< 3 s) and rapidly returned to basal values (in about 5 s and 20 s respectively). The CO also slowly increased peaking 20 s after the end of the test and remaining elevated until about 60 s after the end.

Conclusion:

Attenuated hemodynamic responses in the soleus are likely to reflect a stronger sympathetic vasoconstrictor tone in lower vs. upper limbs. The time course of TOI, very similar in both districts, reveals the local increase in muscle blood flow, and appears adequate to describe the release of ADR in the blood stream. Future studies implementing simultaneous blood sampling and assessment of catecholamine concentration are necessary to validate this proposition.

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3. Training Interventions & Adaptations

P19. Near-infrared spectroscopy assessment of muscle oxidative capacity in healthy young adults following a 4-week HIIT protocol

Giuriato G. (1, 2, 3), Amato M. (3), Monti C. (3)

Maximal oxygen uptake (VO2max) and skeletal muscle oxidative capacity both improve with endurance training. Whether high-intensity interval training (HIIT), as 4 min at 90% alternating with 3 min at 70% maximal aerobic speed, changes peripheral oxidative capacity, and to what extent, is unclear. This study assessed changes in muscle oxidative capacity after 4 weeks of near-maximal HIIT in recreationally active young males, using near-infrared spectroscopy (NIRS) to measure it non-invasively. We hypothesized that VO2max would increase, whereas peripheral oxidative capacity would change little over such a short period.

Six healthy males performed a maximal incremental running test and a NIRS-derived oxidative capacity assessment at the medial gastrocnemius, before and after a 4-week HIIT program (3 days/week; 28 min alternating 4 min at 90% with 3 min at 70% maximal aerobic speed, 1% incline). The oxidative capacity assessment started with a 2–3 min resting baseline, then ~10–15 s of ~1 Hz plantar-flexion contractions raised muscle oxygen consumption (mVO2), followed by an occlusion to minimum TSI (or 5 min) and reactive reoxygenation, defining an individual saturation range. mVO2 was then assessed by desaturating the muscle to ~50% of that range (1) and applying rapid intermittent arterial occlusions (five of 5 s, ten of 10 s, each separated by 10–15 s recovery); mVO2 recovery was characterized by the time constant tau and rate constant k. Arterial occlusion pressure was set within 250–300 mmHg. Data are median [IQR].

VO2max increased from 50.20 [49.65–50.98] to 52.65 [51.67–53.17] mL/min/kg (p=0.023). VE and RQ were unchanged (p=0.759; p=0.519) post-training. Peripheral indices trended favorably but non-significantly: tau shortened from 56.89 [51.19–65.17] to 45.20 [22.04–69.93] s (p=0.29) and k rose from 1.06 [0.92–1.18] to 1.35 [0.89–3.16] min-1 (p=0.09), with high post-training IQR driven by a few low responders.

As hypothesized, 4 weeks of HIIT increased VO2max, whereas peripheral oxidative capacity did not change significantly. The favorable but non-significant mVO2 trends suggest an early peripheral adaptation. Recruitment is ongoing to strengthen power.

P20. Effects of a Two-Week Sprint Interval Training Intervention on NIRS- Derived Skeletal Muscle Oxidative Capacity and Aerobic Fitness

Hanafy M., McManus C., Jones B.

Objective

While aerobic training adaptations are typically evaluated using whole-body measures such as maximal oxygen uptake, less is known about concurrent changes in local skeletal muscle oxidative capacity in vivo after short-term training. This study examined whether two weeks of sprint interval training (SIT) alters skeletal muscle oxidative capacity, assessed using a modified near-infrared spectroscopy (NIRS) method, a six-occlusion protocol (Mito6; McCully et al., 2020), in which plantar flexion exercise was substituted for electrical stimulation, to evaluate whether this measure tracks peripheral changes.

Hypothesis

As muscle biopsy studies report increased oxidative enzyme activity after as few as six SIT sessions, we reasoned that any such peripheral adaptation should be detectable in vivo. We hypothesised that the NIRS-derived recovery rate constant (k), would increase alongside $\dot{V}O_2max$, with no change in the control group.

Methods

Thirty-five recreationally active adults were randomly allocated to a sprint interval training group (SIT; n = 20) or a non-exercising control group (CON; n = 15). The SIT group completed six supervised cycling sessions over two weeks. Muscle oxidative capacity (gastrocnemius) was assessed after a plantar-flexion exercise bout, six transient arterial occlusions tracked the recovery of muscle oxygen consumption ($m\dot{V}O_2$), to derive k. Whole-body fitness was assessed via an incremental cycle ergometer test with breath-by-breath gas analysis ($\dot{V}O_2max$, TTE, PPO).

Results

Gastrocnemius oxidative capacity (k) measured via Mito6 did not change following SIT ($\Delta = 3 \pm 5\%$, $p = 0.21$) and did not differ from CON ($p = 0.34$). In contrast, SIT improved $\dot{V}O_2max$ ($\Delta = 8 \pm 4\%$, $p = 0.003$), TTE ($\Delta = 12 \pm 6\%$, $p = 0.01$), and PPO ($\Delta = 15 \pm 6\%$, $p = 0.002$) relative to CON.

Conclusions

Two weeks of sprint interval training improved whole-body aerobic fitness and exercise performance without a detectable change in NIRS-derived oxidative capacity. Improvements in $\dot{V}O_2max$, TTE, and PPO are consistent with central adaptations to SIT, including plasma volume expansion and enhanced cardiac output (Gibala et al. 2004). The absence of change in gastrocnemius oxidative capacity may reflect the muscle's role as a secondary contributor during cycling. Notably, whilst NIRS-derived $m\dot{V}O_2$ recovery in the gastrocnemius has been shown to differentiate between individuals of high and low aerobic fitness (Lagerwaard et al. 2019), the sensitivity of the recovery rate constant (k), as derived via the Mito6 approach, to detect training-induced change over a two-week window, remains to be established. Future work should examine whether peripheral adaptation emerges over a longer training period, extend measurement to the primary working muscles, and pair NIRS with an independent measure of mitochondrial function (^{31}P-MRS or muscle biopsy) to resolve whether the absence of change reflects genuine physiology or limits of the in vivo measure.

P21. Wearable mNIRS Tracks Longitudinal Changes in Running Metabolic Thresholds Throughout Pregnancy and Postpartum

Kane D., King B., Lee C., Gigante S., Collins, M.

Pregnancy is associated with profound cardiovascular and metabolic adaptations that may alter exercise threshold responses, yet the longitudinal effects on running metabolic thresholds remain poorly understood. Wearable muscle near-infrared spectroscopy (mNIRS) offers a non-invasive means of monitoring local muscle oxygenation during exercise, but its ability to longitudinally monitor metabolic threshold adaptations throughout pregnancy and postpartum has not been established. We hypothesized that individualized mNIRS-derived thresholds would remain closely aligned with blood lactate-derived thresholds despite the substantial physiological adaptations accompanying pregnancy and postpartum recovery.

A recreational runner completed 15 incremental treadmill tests over approximately two years, including one pre-pregnancy assessment, five during pregnancy, and nine postpartum. Blood lactate concentration, vastus lateralis muscle oxygen saturation (SmO2), heart rate, and rating of perceived exertion were measured during each test. Blood lactate-derived lactate threshold 1 (LT1) and lactate threshold 2 (LT2) were compared with individualized mNIRS-derived thresholds.

Running speeds corresponding to LT1 and LT2 progressively declined throughout pregnancy and remained below pre-pregnancy values during the early postpartum period, returning to baseline approximately eight months after delivery. Heart rates at LT1 and LT2 exhibited similar, although smaller, longitudinal changes. Across all 15 assessments, individualized mNIRS-derived LT1 and LT2 consistently corresponded with blood lactate-derived thresholds despite marked physiological adaptations occurring throughout pregnancy and postpartum recovery.

This intensive longitudinal investigation demonstrates that wearable mNIRS can non-invasively track metabolic threshold adaptations throughout pregnancy and postpartum. These findings support individualized muscle oxygen saturation monitoring as a practical tool for longitudinal physiological assessment and exercise prescription when frequent invasive lactate testing is impractical.

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4. Vascular Function, Occlusion & Blood Flow

P22. Microvascular oxygenation responses to a standardized exercise protocol under different occlusion pressures

Martinez-Reviejo Raquel (1), Pretorius Anika (1)(2), Verma Manish (2), Durduran Tutgut (2)(3), Ferrer-Uris Blai (1), and Busquets Albert (1)

Introduction: Blood flow restriction (BFR) training protocols employ occlusion pressures during exercise (40-80% limb occlusion pressure, LOP) to modulate tissue oxygen availability (1,2). However, little is known regarding how different pressure levels impact microcirculation blood flow and oxygen concentration by the end of the training session. This study aimed to characterize pressure-dependent changes in microvascular blood flow and oxygenation dynamics across different relative occlusion intensities at the end of traditional BFR protocol.

Methods: LOP was determined (n=20; 18-29 years; 9 females). During the entire BFR training, relative blood flow (rBF) was assessed via diffuse correlation spectroscopy (DCS) in the medial gastrocnemius muscle. The changes in oxygenated hemoglobin (ΔHbO_2), deoxygenated hemoglobin (ΔHHb), total hemoglobin (ΔHbT), and tissue oxygen saturation (ΔStO_2) were calculated via time-domain NIRS (TD-NIRS). TD-NIRS and DCS were incorporated in a hybrid device with an automated vascular occlusion pump (3). Four sets of 30-15-15-15 isometric plantar flexion were performed, at 30% of the individual's maximum voluntary contraction, with 30s rest intervals after each set. Occlusion pressure was maintained throughout the entire protocol, including rest periods. The same protocol was conducted under five randomized pressure conditions (0%, 40%, 60%, 80%, and 100% LOP). Median values from the final 30s rest period were compared across occlusion pressures using repeated measures ANOVA and Friedman tests.

Results: rBF was highest at 0% LOP ($p \leq 0.01$) and lowest at 100% ($p \leq 0.005$), with no differences among submaximal pressures. ΔHbO_2 at 100% LOP was significantly lower than at 0%, 40%, and 60% ($p \leq 0.003$), while 80% LOP demonstrated intermediate values between 100% and the other pressures. ΔHHb levels were significantly greater at 60%, 80%, and 100% LOP ($p \leq 0.009$) compared to 0% and 40%. ΔStO_2 was significantly lower at 80% LOP and 100% ($p \leq 0.003$) compared to other pressures. In addition, values at 60% LOP were inferior than 0%, while 40% LOP did not differ from either 60% or 0%. Finally, ΔHbT was lower at 0% LOP ($p \leq 0.037$) and 100% ($p \leq 0.035$) compared to other submaximal pressures, although 80% LOP and 100% exhibited similar ΔHbT levels.

Conclusions: Our analysis revealed similar rBF responses between submaximal pressures. However, distinct pressure-dependent oxygenation patterns emerged across occlusion intensities. The 40% LOP condition demonstrated hemodynamic responses comparable to 0%, suggesting incomplete venous outflow restriction. The 60% LOP exhibited ΔHHb values comparable to higher pressures (80%, 100%). However, its more elevated ΔStO_2 levels likely reflect greater ΔHbO_2 inflow relative to ΔHbT, due to less severe arterial restriction than these superior pressures. Finally, 80% LOP showed similar oxygen dynamics to 100% but with higher rBF, indicating incomplete arterial restriction despite similar oxygenation patterns.

P23. Exploring hemodynamic mechanisms with time-resolved NIRS at different levels of limb occlusion pressure during blood flow restriction exercise

Murdoch-Pretorius, A., Martinez-Reviejo, R., Verma, M., Durduran, T., Ferrer-Uris, B., Busquets, A.

Introduction: Low-load training with a cuff pressure applied to the limb has long been used to stimulate muscular adaptations comparable with high-load training. The original Japanese term kaatsu (ka = add, atsu = pressure) meant training with added pressure, implying mechanisms related to elevation in intra-muscular/ -vascular pressure, while the current term blood flow restriction (BFR), suggest oxygen delivery restriction mechanisms. Indeed, the underlying physiology encompasses both, yet, the relative contribution of these mechanisms is likely pressure-dependent, and guidelines recommend a broad range of 40-80% of individual limb occlusion pressure (LOP) 1. Therefore, in this study we aimed to explore hemodynamic mechanisms at different LOP levels. Methods: We determined individual LOP and measured local muscle hemodynamics during five separate sessions at 0, 40, 60, 80 & 100% LOP, respectively, during a standard BFR protocol1 including alternating exercise (1 x 2 min + 4 x 1 min plantar flexions at 30% maximal isometric force and 0.25 Hz contraction-relaxation cycles) interspersed with 30 s rest phases. Results: Fig. 1 illustrates the steady state parts within the last 20 s of exercise phases with statistically significant different values from control (0% LOP) indicated (one-way ANOVA and Bonferroni post-hoc correction).

Discussion: At higher pressures, StO2 was lower at 80-100% and HbO2 at 100% LOP, pointing to oxygen restricted mechanisms. When considering HbO2 and HHb dynamics as the components of StO2, the lowered StO2 at 80% LOP was caused by HHb accumulation due to venous outflow restriction, while HbO2 was only reduced at 100% LOP. From the increases in tHb at low pressures (40-60% LOP) it may be suggested that mechanical pressure related mechanisms is dominant here (i.e., blood pooling increased intravascular pressure). Conclusion: Our findings support the claim that the

physiological effects are dominated by different mechanisms at different pressures. This could allow for the establishment of mechanism-based goals adjusted by concurrent monitoring.

P24. NIRS-derived reperfusion rate is not correlated with retinal microvascular reactivity: preliminary findings

Michael Mendes Wefelnberg

Study aim and hypothesis: In this work, we tested the hypothesis that the near-infrared spectroscopy (NIRS)-derived reperfusion rate (slope 2) of tissue oxygen saturation (StO2) is associated with retinal microvascular reactivity. Microvascular reactivity was measured via dynamic retinal vessel analysis (DRVA)-derived parameters—specifically, arterial and venous flicker-induced dilation (aFID,vFID) and arterial constriction (aCON), which are commonly used biomarkers for assessing vascular endothelial function in humans.

Methods: In this study, 10 healthy normotensive participants (age 30±5 years, 4M/6F, BMI 23±2 kg·m-2, MAP 87±8 mmHg) had passed medical clearance and completed three laboratory visits. During the first lab visit they performed a cardiopulmonary exercise test (CPET) until voluntarily exhaustion. During the second lab-visit their microvascular endothelial function was assessed using the DRVA (Imedos Health, Jena, Germany) of the dominant eye, while the vascular occlusion test of the m. flexor digitorum superficialis of the dominant arm was performed on the third visit using blood pressure cuff (Boso classic, Bosch+Sohn, Jungingen, Germany) inflated to 200 mmHg and Train.Red Pro NIRS system (Elst, the Netherlands).

Results: The average V̇O2 peak was 39±3 ml·min·kg-1, while the peak power output was 240±52 W. The average aFID, vFID and aCON readings were 4.1±2%, 5.6±1.2% and -2.1±1.3%, respectively. The baseline of NIRS-derived StO2 was 77.5 ± 3.8 %, slope 1 was -0.157 ± 0.06 %·s-1, slope 2 was 2.429 ± 1.149 %·s-1, while the area under the curve was 1247 ± 626. There was no correlation between the reperfusion rate (slope 2) or any DRVA-derived parameters test (r= -0.420, p=0.227; r= -0.315, p=0.325; r= -0.169, p= 0.640).

Conclusion: Apparently, these preliminary findings suggest no association between the slope 2 of the VOT test and DRVA-derived biomarkers of the retina microcirculation. However, a correlation analysis does not imply causality, especially within limited sample size, and further research is warranted to explore the association between the reperfusion rate (slope 2) of the VOT and DRVA-derived parameters in both healthy and diseased populations.

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5. Clinical Applications & Special Populations

P25. O2 flow limitation with aging: in vivo and ex vivo evidence of a shift from muscle diffusive to oxidative limitation

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Aging is associated with a decline in cardio-respiratory function (1). Alterations in muscle microvasculature and mitochondrial spatial organization can constrain intramuscular O2 flow influencing O2 diffusion and utilization. We assessed age-related changes in functional

characteristics of muscle oxidative capacity and O2 diffusion, alongside structural microvascular and mitochondrial variables related to oxidative metabolism.

Ten young (YG:29±4yrs) and twelve old (O:79±4yrs) healthy males performed an incremental cycling test to determine V̇O2peak. Vastus lateralis (VL) V̇O2 recovery rate (k) was assessed by near-infrared spectroscopy (NIRS) using repeated post-exercise occlusions. Occlusion timing and duration were adjusted to maintain tissue saturation index within two O2 availability conditions: non-limiting (HIGH) and limiting (LOW). kHIGH estimates muscle oxidative capacity; the difference between kHIGH and kLOW (Δk) reflects relative O2 diffusion limitation (2). Capillaries around-fiber (CAF), mean capillary-to-sarcolemma diffusion distance (mCtSDD), and subsarcolemmal (SS) and intermyofibrillar (IMF) mitochondrial content were determined from VL biopsy.

V̇O2peak was lower in O than YG (24.2±4.3 vs 47.4±5.3ml·kg^{-1}·min^{-1};$p<0.001$). kHIGH (YG:2.85±1.02 vs O:1.97±0.39min^{-1};$p<0.05$) and Δk (YG:1.26±0.94 vs O:0.58±0.39min^{-1};$p<0.05$) were greater in YG. V̇O$_2$peak correlated with kHIGH ($r=0.59$;$p<0.01$) and Δk ($r=0.61$;$p<0.01$). Compared with YG, O had lower CAF (YG:2.83±0.59 vs O:1.40±0.60;$p<0.01$), greater mCtSDD (YG:13.3±1.46 vs O:18.0±3.4µm;$p<0.05$), and lower SS and IMF mitochondrial content ($p<0.01$).

Age-related changes in aerobic capacity were associated with impaired muscle oxidative function and decreased sensitivity to low O2 availability. Old males also showed alterations in microvascular structure and mitochondrial organization. Thus, aging may reduce the overall capacity for diffusive O2 flux, but the control of muscle O2 consumption shifts towards oxidative/metabolic processes during recovery from exercise.

P26. Bed rest (21-d without countermeasures) decreases resting skeletal muscle O2 uptake and resting energy expenditure: influence of sex

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A decrease in resting muscle O2 uptake (V'O2m), associated with a decreased whole-body resting energy expenditure (REE), has been described by our group in male subjects exposed to bed rest (BR). This study aimed to confirm the effects on resting V'O2m and REE of a 21-day -6° head-down tilt BR, with no countermeasures, in males (M) and females (F). Moreover, we investigated if the observed changes were reversible after BR termination, and if they were associated with changes in the equilibrium between the "super-relaxed state" (SRX) and "disordered relaxed state" (DRX) of myosin.

Two groups of recreationally active people (M, n=11, age 24±6 years; F, n=9, 25±5 years) were studied. Measurements were performed before BR (BDC), at the end of BR (BR21) and after 21 days of reconditioning (R21).

Adipose tissue thickness (ATT) at the site of application of the near-infrared spectroscopy (NIRS) probe was measured by echography. Resting V'O2m was determined by NIRS, in the vastus lateralis muscle, by the slope of the linear increase in muscle deoxygenation during a 60-s limb ischemia. REE was measured by open-circuit spirometry and standard methods. SRX-DRX equilibrium of myosin was evaluated by determining ATPase activity (mantATP chasing) on vastus lateralis muscle fibers obtained by biopsy.

ATT was higher in F vs M. In both M and F resting V'O2m significantly decreased at BR21 vs BDC (-43% in M and -58% in F). The same occurred for REE (-9% in M and -9% in F). These variables did not fully recover to BDC values at R21. The DRX-SRX equilibrium of myosin data are being analyzed.

In conclusion, both M and F showed decreases in resting V'O2m and REE during 21 days of BR without countermeasures. Full recovery was not achieved after 21 days of reconditioning. The downregulation of resting V'O2m and REE may represent a 'recalibration' of ATP supply to a reduced ATP demand, aimed at preventing excessive reactive oxygen species production and muscle atrophy. This adaptation could mitigate biological and logistical challenges, and could reduce the damage by cosmic radiations, during prolonged spaceflights. The role of the equilibrium between the SRX and DRX states of myosin on the observed resting V'O2m and REE decreases will be determined.

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P27. Simulation-Driven Multi-Wavelength Wearable NIRS Framework for Early Migraine-Related Hemodynamic Monitoring

Keshavarz A., Alavi M.

Migraine prodrome may involve subtle hemodynamic alterations before headache onset, creating opportunities for early physiological monitoring. The objective of this study was to develop a simulation-driven multi-wavelength wearable NIRS framework for investigating prodrome-related hemodynamic dynamics under realistic low-SNR conditions. We hypothesized that combining multi-wavelength optical modeling, source–detector geometry analysis, and signal processing could improve interpretation of subtle oxyhemoglobin (HbO) and deoxyhemoglobin (HbR) variations.

A four-layer head model consisting of scalp, skull, cerebrospinal fluid, and cortex was used. Diffusion-informed simulations were performed at 760, 830, and 950 nm. Source–detector separations between 10 and 35 mm were evaluated to investigate cortical sensitivity and signal attenuation. Synthetic HbO/HbR trajectories were generated over a 180-min pre-onset period with physiological oscillations, baseline drift, and stochastic noise.

Generated data included depth-dependent fluence profiles, attenuation coefficients, relative cortical sensitivity, wavelength-dependent HbO/HbR sensitivity, and noisy and filtered hemodynamic signals. Effective attenuation decreased from 0.271 mm^{-1} at 760 nm to 0.214 mm^{-1} at 830 nm and 0.176 mm^{-1} at 950 nm, indicating improved penetration at longer wavelengths. Long-separation channels (20–35 mm) provided greater cortical sensitivity than short separations. Wavelength analysis demonstrated complementary physiological sensitivity, with 760 nm favoring HbR detection, 950 nm favoring HbO detection, and 830 nm providing balanced reference behavior. Signal filtering improved visualization of gradual prodrome-related trends in low-SNR conditions.

These findings support the feasibility of a simulation-driven wearable NIRS framework for migraine-related hemodynamic monitoring and establish a foundation for future AI-assisted interpretation and experimental validation. Although demonstrated using a cerebral hemodynamic model, the framework can be readily adapted to wearable NIRS investigations of peripheral and muscle hemodynamics.

P28. Exercise Intolerance and Return to Sports in Survivors of Pediatric Hematologic Malignancies

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Introduction:

Children and adolescents treated for hematologic malignancies often present with reduced exercise capacity due to the combined effects of disease, treatment, and prolonged inactivity. Near-infrared spectroscopy (NIRS) may provide a useful tool to assess skeletal muscle oxygen extraction and peripheral exercise intolerance in this population (1). Early implementation of a personalized exercise program (PEx) may help limit the persistence of these impairments into survivorship. Accurate assessment of residual exercise tolerance is essential to guide individualized interventions.

Methods:

Patients aged 9–21 years with blood cancers were assessed at the start of maintenance therapy or at the end of treatment. Evaluations included a maximal cardiopulmonary exercise test (CPET) and functional performance tests. Key variables analyzed were peak oxygen consumption (VO_2peak) and muscle oxygen extraction using near-infrared spectroscopy (NIRS, HHb/isch).

Results:

Twenty-six participants (mean age: 14.5 years; 58% female) completed the assessments. Diagnoses included acute lymphoblastic leukemia, acute myeloid leukemia, and lymphomas (11% had undergone hematopoietic stem cell transplantation). At the time of evaluation, 42% were in the maintenance phase and 58% were off therapy for less than 12 months. Compared to healthy controls, participants exhibited a 32% reduction in VO_2peak (range: 48–94%) and a 36% reduction in HHb/isch (range: 25–100%).

Conclusions:

Exercise intolerance persists during early survivorship, with considerable individual variability. Early implementation of structured PEx programs may facilitate the reintegration of pediatric cancer survivors into daily life and physical activity, including sports participation.

P29. Wearable Multichannel Near-Infrared Spectroscopy for Continuous Compartment-Specific Monitoring of Acute Compartment Syndrome

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Objective: Acute compartment syndrome (ACS) is a limb-threatening condition whose diagnosis currently relies on clinical assessment and invasive intracompartmental pressure measurements. Near-infrared spectroscopy (NIRS) has shown promise as a noninvasive alternative for monitoring skeletal muscle oxygenation in ACS, but previous clinical studies have been limited by poor signal reliability and single-site measurements (Garr et al., 1999; Schmidt et al., 2018). We evaluated the feasibility of a wearable multichannel NIRS system for continuous, compartment-specific monitoring of skeletal muscle oxygenation.

Methods: Healthy adults (n=14, pilot cohort) performed compartment-specific isometric exercises targeting the anterior, lateral, and posterior compartments of the lower leg while muscle oxygen saturation (StO_2) was continuously measured using a custom wireless NIRS system. Three modular sensing patches provided simultaneous monitoring across compartments using multiple source-detector separations (2–4 cm). StO_2 was calculated using the modified Beer–Lambert law and compared between rest and exercise. Group-averaged, participant-optimized, and redundant-channel analyses were performed.

Results: Exercise produced reproducible transient decreases in StO_2 followed by recovery during rest, consistent with expected physiological responses (Westman et al., 2023). Significant reductions from baseline were observed in the anterior (Table 1) and lateral compartments, whereas the posterior compartment demonstrated smaller, nonsignificant changes, likely reflecting anatomical and physiological differences. Participant-specific channel optimization improved

response magnitude and statistical significance, while the redundant sensing channel increased measurement robustness and preserved physiologically meaningful responses when channel performance varied.

Conclusions: This pilot study demonstrates the feasibility of continuous, multichannel NIRS for compartment-specific monitoring of skeletal muscle oxygenation. Customizable source-detector geometry and redundant sensing address limitations of conventional single-site NIRS systems and support future clinical validation for early, noninvasive detection of ACS.