Spatial Distributions of Forearm Hemodynamic Responses During Isometric Handgrip Exercise

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INTRODUCTION

Understanding regional blood flow and oxygenation dynamics in skeletal muscles is essential for optimizing rehabilitation and athletic interventions.

Forearm muscles, crucial for fine motor tasks and grip strength, rely on precise vascular adjustments to match metabolic demands.

Recent Near-Infrared Spectroscopy (NIRS) studies revealed significant spatial variability in forearm muscle oxygenation, underscoring the complexity of localized hemodynamic evaluation.

Investigating how exercise intensity, duration, and muscle involvement influence these spatial responses can inform targeted rehabilitation strategies for conditions such as peripheral artery disease and post-stroke recovery and enhance athletic performance by optimizing blood flow to specific muscle regions.

OBJECTIVE

To explore how spatial factors affect hemodynamic and oxygenation responses of the forearm during varying intensity, duration, and muscle mass protocols of isometric handgrip exercise using near-infrared spectroscopy (NIRS).

KEYWORDS

- Isometric Contraction
- Near-Infrared Spectroscopy
- Hemodynamics
- Handgrip exercise
- Forearm Muscles

METHODS

Participants

Our participants were 16 healthy adults.

- Age = 25.07 ± 0.55 yr
- Height = 174.40 ± 1.76 cm
- Weight = 67.83 ± 3.88 kg
- Body mass index (BMI) = 22.11±0.97 kg/m²
- Gender = 9 males and 7 females.

Setting

University research lab with trained researchers, with temperature control at 21° C (70° F).

Design

Cross-sectional with before-after trial

Protocols

A: 30% MVC, 2 min, dominant hand
B: 45% MVC, 2 min, dominant hand
C: 30% MVC, 3 min, dominant hand
D: 30% MVC, 2 min, bilateral

- Muscle hemodynamic responses were measured 5 minutes before and after each exercise

Device

❑ fNIR Imager 1000, fNIR Devices LLC, Potomac, Maryland

- NIRS signals were sampled at a frequency of 2 Hz.
- Raw fNIRS signals underwent low-pass filtering through a finite impulse response filter with a cutoff frequency of 0.14 Hz
- 16-channel NIRS optical device placed on the forearm of the dominant hand of the participant.

Outcome Measures

Oxyhemoglobin (HbO2), Deoxy-hemoglobin (Hb), Total hemoglobin (tHb), Oxygenation (O2)

Regions Analyzed

Proximal, Middle-Proximal, Middle-Distal, Distal forearm

RESULTS

Our results indicate that total blood volume and oxygenation exhibit a larger change in the proximal and middle-proximal parts of the forearm compared to the distal and middle-distal parts when the intensity, duration, and muscle mass factors of isometric contraction are increased.

Oxyhemoglobin (HbO2):

Greatest changes observed in middle-distal (Protocol A: 1.43 ± 0.41; Protocol B: 1.38 ± 0.81) and distal regions (Protocol C: 1.88 ± 0.69).

- Proximal regions showed less variation.

Deoxyhemoglobin (Hb)

Greatest positive changes predominantly in distal and middle-proximal regions during protocols B and C.
Distal region: Protocol B (1.28 ± 0.55)

Total Hemoglobin (tHb)

Highest responses in proximal and middle-proximal regions, particularly Protocol B (Proximal: 3.21 ± 1.30; Middle-Proximal: 3.19 ± 1.29).

Oxygenation

Elevated primarily in middle-distal and distal regions, especially under Protocol C (Middle-Distal: 1.94 ± 0.98; Distal: 1.79 ± 1.05).

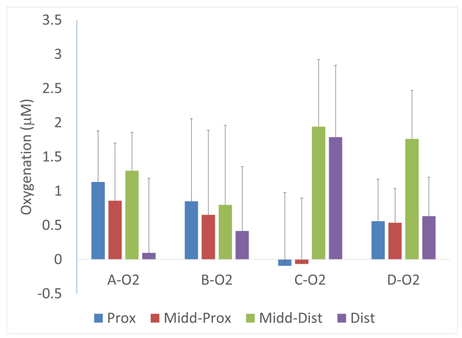


Fig 1. Oxygenation (μM) across spatial areas of the forearm

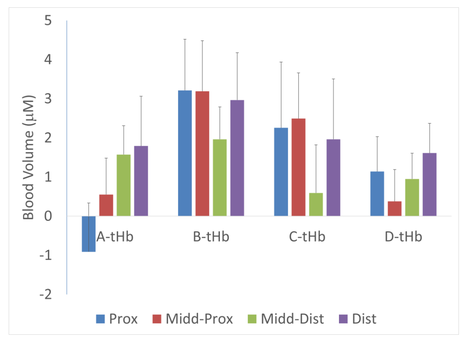


Fig 2. Total Blood Volume (μM) across spatial areas of the forearm

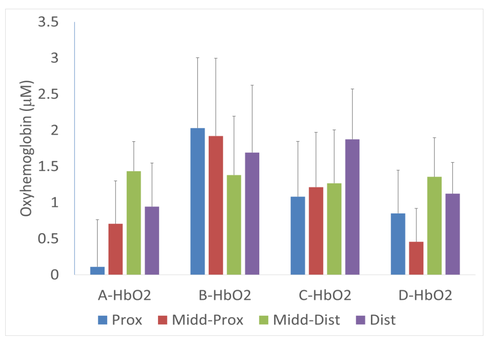


Fig 3. Oxyhemoglobin (μM) across spatial areas of the forearm

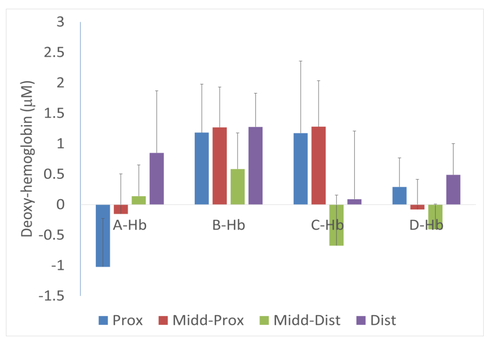


Fig 4. Deoxy-hemoglobin (μM) across spatial areas of the forearm

CONCLUSIONS

Our results demonstrate regional differences in forearm hemodynamic responses. Increased intensity, duration, and bilateral conditions preferentially affect proximal and middle-proximal areas, suggesting targeted exercise prescriptions could enhance regional vascular.

- Improved rehabilitation protocols tailored to regional vascular demands.
- Potential enhancements in clinical and sports-related vascular health assessments.

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