EVALUATION OF A WEARABLE BIOMONITORING DEVICE DURING DRY AND SUBMERGED CONDITIONS WITH AND WITHOUT EXERCISE

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INTRODUCTION

- Non-invasive wearable monitors provide a significant potential for continuous health assessments in dynamic environments.
- Reliable underwater physiologic monitoring technology is currently unavailable.
- Development of an underwater biomedical monitor with continuous monitoring capability could provide physiological data on potential factors that can influence the safety and success of operational diving.
  - Specifically, monitoring peripheral oxygen saturation (SpO_2), tissue oxygen saturation (StO_2), and heart rate (HR) may support assessment of both systemic oxygenation and localized tissue perfusion to enable timely safety maneuvers.
- This study evaluated the experimental SP *Argus* devices' operational performance, repeatability, and responses as a biological monitor to measure SpO_2, StO_2, and HR on the surface, in 2 feet of fresh water (ffw), and 12 ffw with normoxic and hypoxic breathing gases at 3 anatomic loci: forearm (F), sternum (S), and vastus lateralis (VL) under conditions that would elicit changes in systemic oxygen saturation.
  - This study did not aim to validate accuracy against a gold standard.

METHODS

- 12 subjects (aged: 33 ± 6 yrs, height 177 ± 3 cm, weight 92 ± 15 kg, years experience diving: 9 ± 4 yrs) participated in this study.
- Each subject underwent the same testing over two days for test-retest reliability measures (Figure 1)
  - Measurements were collected in two environments: surface and submersion
    - Each environment consisted of two conditions: rest and exercise
      - In each condition two gases were breathed to compare physiological conditions between environments: normoxia (0.21 atm) and hypoxia (0.13 atm) (see Figure 1).
- A survey about form, fit, and function of the devices was given to each diver after testing

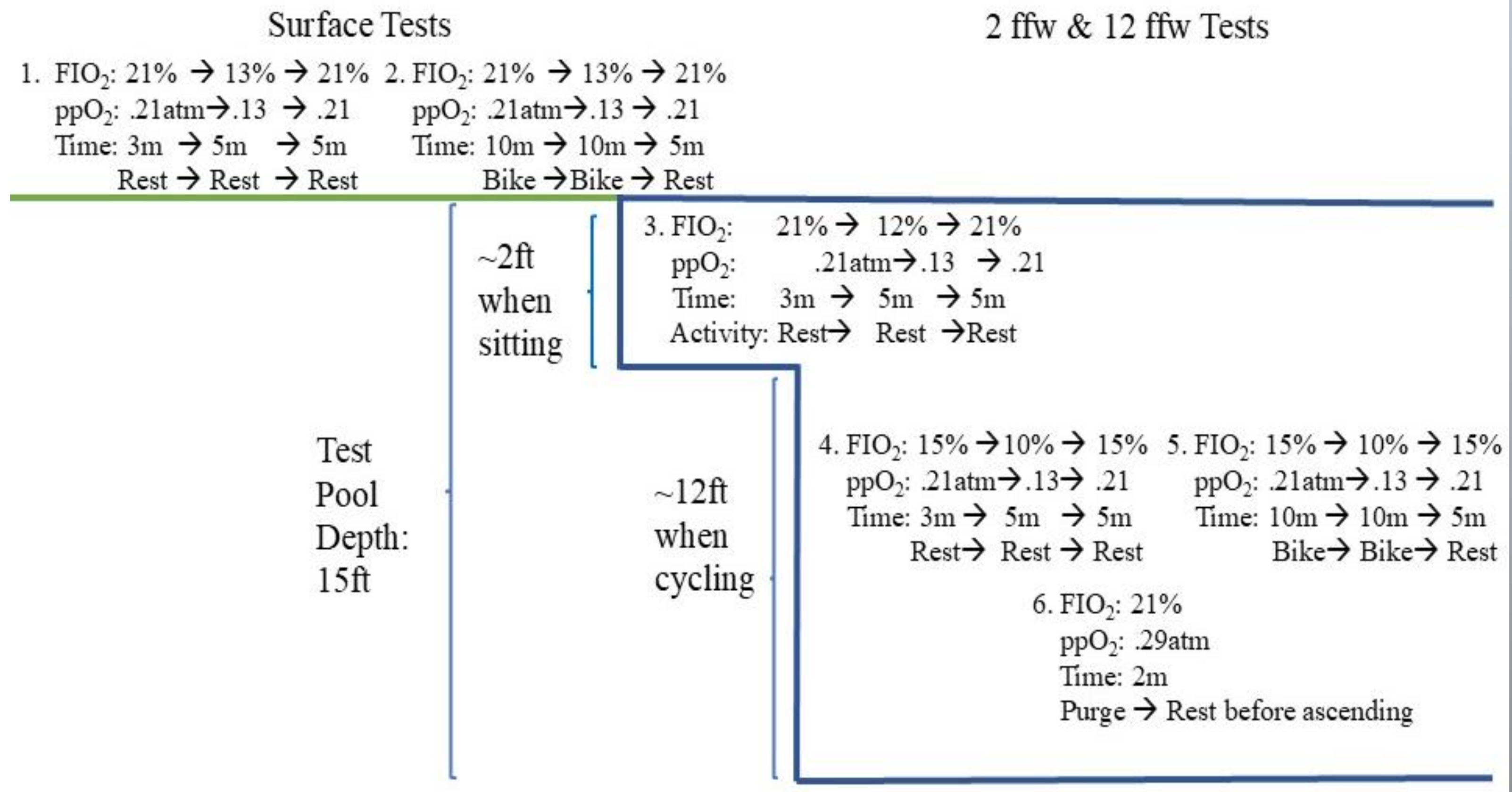

Figure 1. Experimental Design

RESULTS – RELIABILITY

- Only StO_2 data are reported because the device did not consistently generate physiologically plausible SpO_2 and HR measurements.
  - SpO_2 and HR values were either not collected by the device (i.e. drop-out data) or data did not meet physiologic values when breathing normoxic or hypoxic gases during rest or exercise.[1,2]

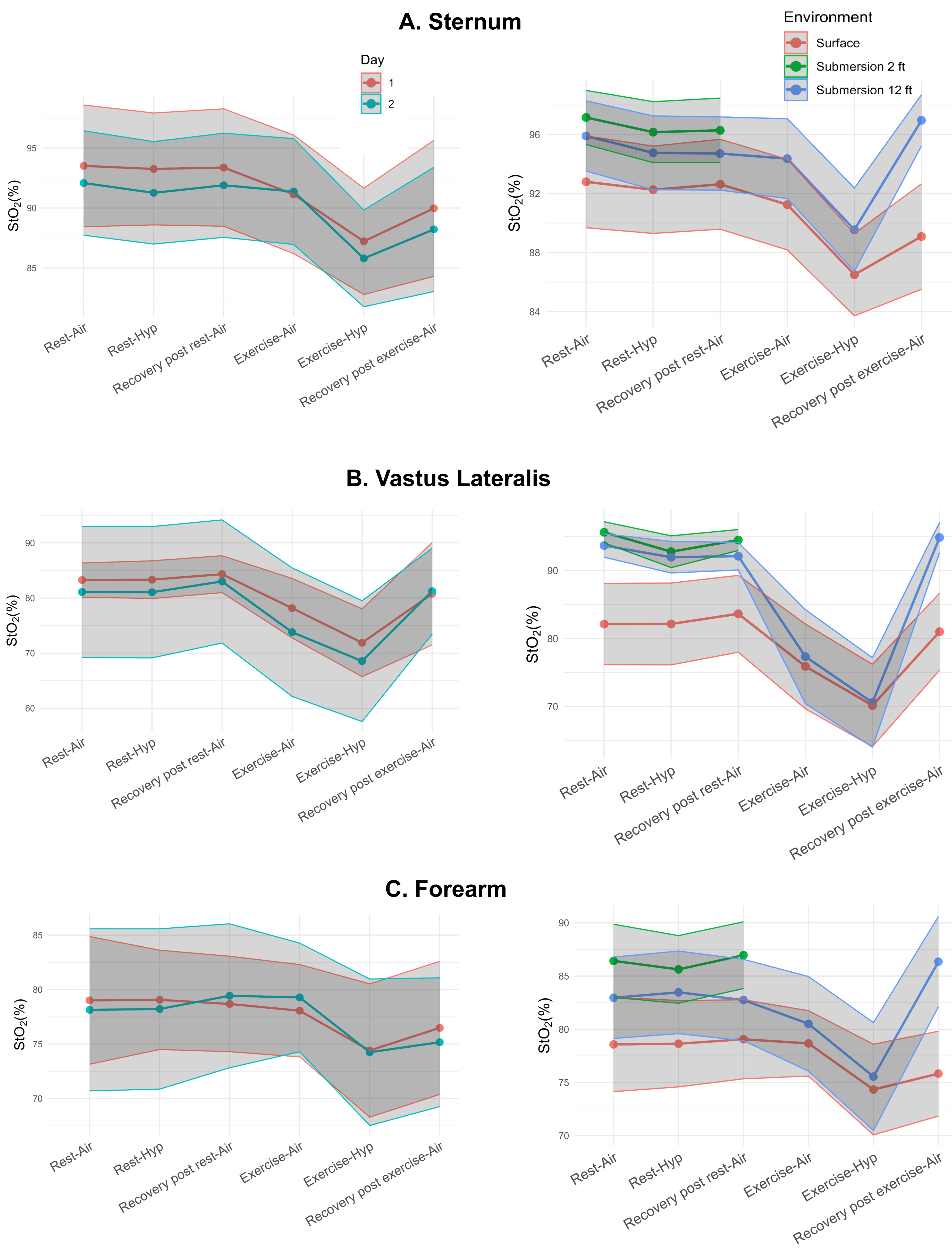

Figure 2. Test, Retest Reliability. Images on the left of each anatomic location heading show reliability between days and images on the right show reliability between environments. Mean StO_2 with 95% confidence interval in gray. "Air" is defined as a ppO2 of 0.21-0.22 atm and "Hyp" is defined as a ppO2 of 0.13 atm.

RESULTS – ICC

Location.	Comparison	ICC 2,1	ICC 3,1
Sternum	surface and submersion 12ffw air	0.798	0.963
Sternum	surface and submersion 12ffw hyp	0.793	0.892
Sternum	surface and submersion 12ffw rest	0.838	0.938
Sternum	surface and submersion 12ffw ex	0.825	0.917
Vastus Lateralis	surface and submersion 12ffw air	0.729	0.894
Vastus Lateralis	surface and submersion 12ffw hyp	0.844	0.880
Vastus Lateralis	surface and submersion 12ffw rest	0.643	0.882
Vastus Lateralis	surface and submersion 12ffw ex	0.984	0.984
Forearm	surface and submersion 12ffw air	0.862	0.939
Forearm	surface and submersion 12ffw hyp	0.863	0.866
Forearm	surface and submersion 12ffw rest	0.874	0.917
Forearm	surface and submersion 12ffw ex	0.868	0.86

Table 1. Test, Re-test Reliability between Environments and Condition. ICC values are provided. Values in 2,1 column show absolute agreement and values in 3,1 column display consistency. Higher values indicate better agreement and consistency (<0.5, poor; 0.5-0.75, moderate; 0.75-0.9 good; >0.9 excellent reliability)

CONCLUSIONS

- StO_2 data were reliably collected within physiological ranges across all test days, environments and conditions, and anatomic locations.
  - SpO_2 and HR algorithms/models and/or device hardware should be modified to more accurately measure physiological responses
- ICCs showed overall good reliability for StO2 between days, environment, and condition
- Sternum yielded the highest reliability, possibly due to lower perceived movement.
- Vastus Lateralis showed highest variability likely due to movement artifacts
- Beyond data collection, the primary operational challenge was maintaining device adhesion
  - A secure sternum strap might mitigate future adhesion failures.
- Recommend sternum placement for future device iterations to ensure maximum reliability and seamless integration with existing equipment.

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