Exhaled nitric oxide following repeated 6-hour immersed exercise dives at 1.35 atm

Fothergill DM[1], Florian JP[2], and Shykoff BE[2]

[1]*Naval Submarine Medical Research Laboratory, Box 900, Groton, CT, USA, 06349-5900*

[2]*Naval Experimental Diving Unit, 231 Bullfinch Road, Panama City, FL, USA 32407*

INTRODUCTION

Background

Previous research conducted at the Naval Submarine Medical Research Laboratory, Groton, CT has shown that exhaled nitric oxide (NO_{exp}) temporarily decreases following dry resting hyperbaric oxygen exposures in a dose dependent manner (see Figure 1). The strong relationship between the post-dive relative change in NO_{exp} and the hyperoxic dose of the preceding dive suggests that NO_{exp} may provide a useful noninvasive measure of lung oxidative stress following prolonged hyperoxic exposures. As all the previous hyperoxic exposures were conducted in the dry and at rest it was unknown if the relationship in Fig 1 would hold true for more operationally relevant dives involving consecutive multi-day exposures with submersed exercise.

Objective

To determine if consecutive multi-day dives, immersion and exercise significantly affect the post-dive hyperoxic mediated decrease in NO_{exp}.

METHODS

Twelve military divers volunteered to conduct five six-hour dives on sequential days breathing 100% oxygen at 1.35 atm in a heated pool. Throughout each dive they performed repeated bouts of 30 min of prone bicycle exercise (target heart rate of 95±5 beats/min) and 30 min of seated rest (see Fig 2). A separate control group of military divers (n=14) conducted the same multi-day dive profile with the same exercise protocol except that they breathed compressed air at 1.35 atm. Water Temp 87 ± 3 °F (31 ± 2 °C).
18 hr surface interval between dives.

Measurement of Exhaled Nitric Oxide

Niox Mino, Aerocrine Inc, Sweden (see Fig 3)

(electrochemical sensor technology)

- Measurement range: 5 – 300 ppb
- Lowest Detection Limit: 5 ppb
- Analytical Accuracy: ± 5 ppb or max 15%
- Exhalation time: 10 s at an exhalation pressure of 10 – 20 cm H_2O, to maintain a fixed flow rate of 50 ± 5 mL/s.
- NO_{exp} value = mean of 2 measurements that are within 4 ppb , if not within 4 ppb take median of 3 measurements

- NO_{exp} measured:
- immediately before each dive
  after each dive within 30 min of exiting the water
  on recovery day 1
  on recovery day

Fig 3: The Niox Mino portable nitric oxide analyzer.

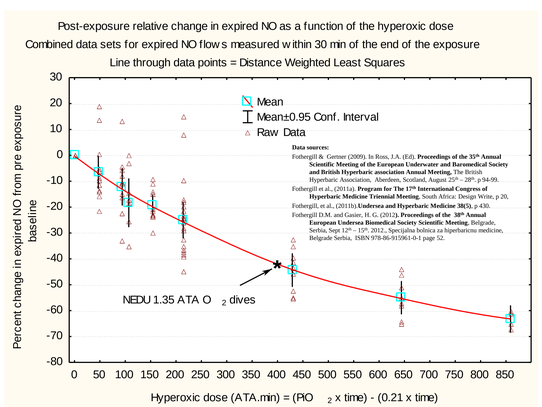

Fig 1: Post exposure relative change in NOexp as a function of oxygen dose for dry, resting hyperoxic exposures. Multiple linear regression analysis of these data using the methods of Bland & Altman (1995) demonstrated a highly significant relationship (r = -0.857; p<0.00001). The results of the current NEDU 6 hr 1.35 ATA O_2 dives are also shown.

Fig 2: Subjects exercising on underwater cycle ergometers in the Navy Experimental Diving Unit test pool.

ACKNOWLEDGMENTS

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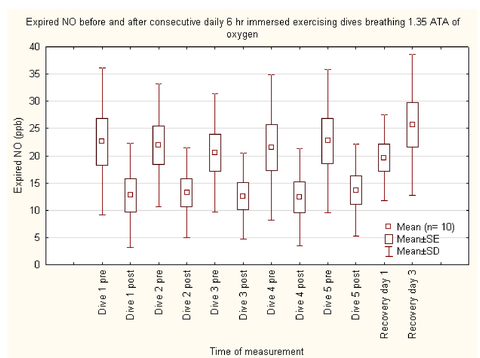
RESULTS



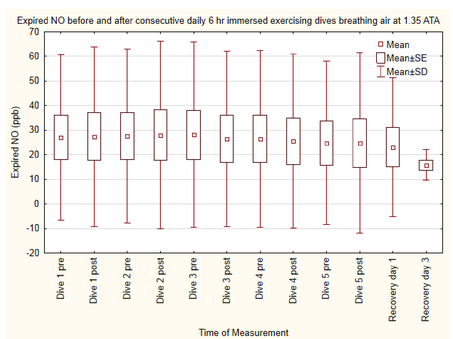
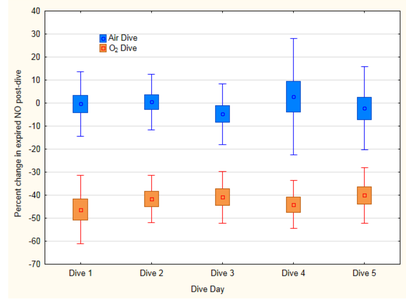


Fig 4: Expired NO before and after each 6 hour immersed O_2 dive (PiO_2 = 1.35 ATA) and 1.35 ATA air dive. Two divers failed to complete the full set of 5 oxygen dives. One subject completed only the first O_2 dive and the other subject completed two of the O_2 dives. Repeated Measures ANOVA comparing the pre-dive NO and recovery values for the oxygen dives was significant (p = 0.048) because of a significant difference between recovery day 1 and recovery day 3 (p = 0.0233); all other pre O_2-dive comparisons were not significantly different. All 14 subjects completed the full 5 dive air series, however the n for recovery Day 1 and recovery Day 3 was 13 and 10 respectively. The post-air dive NO_{exp} did not differ significantly from the pre air dive values at any point during the dive week (p=0.643; n=14).

Fig 6: Relative decrease in NO_{exp} following the 1.35 ATA, 6 hour O_2 and air dives. Data are means ±1SE (boxes) and ±1SD (whiskers). The O_2 dives resulted in a significant decrease in the post-dive NO_{exp} (mean across the 5 days = -42.4% , repeated measures ANOVA, p<0.0001; n=10) that did not differ significantly in magnitude across days (repeated measures ANOVA, p=0.506). The mean relative decrease in NO_{exp} for the 6 h 1.35 ATA O_2 dive, (which has an oxygen dose of 410 ATA.min), falls almost exactly on the curve in Figure 1. The mean±SD relative change in NO_{exp} following the air dives was between +2.8±25.2% and -4.8±13.2%, and is within the expected normal daily variation for NO_{exp}.



CONCLUSIONS

Immersion and mild exercise do not significantly affect the hyperoxic mediated post-dive decrease in NO_{exp}. Consecutive multi-day dives also do not appear to modulate the magnitude of the hyperoxic mediated post-dive decrease in NO_{exp}.

DISCLAIMER