Effects of Consecutive, Long-Duration Hyperoxic Water Immersions on Neuromuscular Performance in Well-Trained, Male Divers

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ABSTRACT

PURPOSE - To investigate the physiological effects of single and repetitive diving-induced hyperoxic conditions on neuromuscular performance at 1.35 atmospheres absolute (ATA). METHODS - This study was conducted as a single-blind, placebo-controlled, repeated measures, within-subjects study (n = 20) that involved 4 days of consecutive diving at 1.35 ATA. Diving consisted of a single hyperoxic phase followed by a remainder recovery period in normoxic (Air) conditions. RESULTS - Significant decreases were seen in maximal strength performance on W1 (MVC knee extension: 3.4%, p=0.001; O2; 4.5%, p=0.016; MVC elbow flexion: 3.5%, p=0.002 combined group result) with recovery occurring by W5. O2 group knee extensor neuromuscular activation decreased by 10% throughout the DW and remained reduced by 14% through the 72-hr post-WI. The Air group neuromuscular activation increased throughout the DW but returned to baseline by 72 hr post-dive. Combined group maximal WI elbow flexion and MVC strength performance decreased by 4% and 5%, respectively, throughout the DW (W1 > W2 and W5, p<0.001). CONCLUSION - Consecutive, resting long-duration normoxic and hyperoxic WIs cause noticeable decrements in muscular strength performance after three days of WIs with recovery seen by 24-hr post-WI. Hyperoxic WIs caused significant reductions to neuromuscular activation. Further research should examine the causes of hyperoxic-induced decreased neuromuscular activity.

BACKGROUND AND SIGNIFICANCE

• Recreational, scientific, or military diving operations may require personnel to be immersed and active for extended periods of time while breathing air and 100% O2 at 1.35 atmospheres absolute (ATA).
• Previous investigations of consecutive, long-duration, hyperoxic WIs at 1.35 ATA demonstrated a 10% reduction in maximum handgrip (MHG) force with post-water immersion (WI) performance being greater than pre-WI performance.

OBJECTIVE

• To further characterize physical performance by conducting static and dynamic muscular exercises following repeated, resting normoxic and hyperoxic WIs at 1.35 ATA.

METHODS

Subjects. Twenty-eight (Air: n=15; O2: n=13), healthy, active duty, male U.S. Navy divers who were nonsmokers and not taking any medications participated in the study. Subjects refrained from alcohol consumption and supplements during testing.

Experimental design. Two phases denoting different inspired gases: Air and 100% O2.

Dive week (DN) consisting of five consecutive 6-hr WIs at 1.35 ATA with 18-hr surface intervals.

Static and dynamic muscular exercises such as maximum voluntary isometric contractions (MVIC) and maximum isometric (IK) contractions knee extension and elbow flexions, and MHG were performed.

All measurements occurred immediately before (pre-WI) and after (post-WI) each WI, with 24 and 72-hr post-WI measurements after the 8th WI.

Surface electromyography (sEMG) via normalized amplitude was used to measure neuromuscular activation.

Mixed method analysis of variance with repeated measures and Bonferroni-Holm correction post hoc tests were used for statistical analysis.

RESULTS – MVC Knee Extension

Figure 1. MVC knee extension performance and sEMG results. Across subject (Air group: n=15; O2 group: n=13) mean ± SEM is shown, pre-dive (x), post-dive (x), 24-hr post-dive (x), & 72-hr post-dive (x) for the dive week. Neuromuscular activation percent change by day (right graph). O2 group (x) and Air group (x) for percent change. “ ■ ” = pre/post-WI main effect (p<0.05). “ ■ ” = day main effect (p<0.05).

RESULTS – MVC Elbow Flexion

Figure 2. MVC elbow flexion performance results. Across subject (Air group: n=15; O2 group: n=13) mean ± SEM is shown, pre-dive (x), post-dive (x), 24-hr post-dive (x), & 72-hr post-dive (x) for the dive week. Neuromuscular activation percent change by day (right graph). O2 group (x) and Air group (x) for percent change. “ ■ ” = pre/post-WI main effect (p<0.05). “ ■ ” = day main effect (p<0.05).

RESULTS – Maximum IK Elbow Flexion

Figure 3. Maximum IK elbow flexion performance results. pre-dive (x), post-dive (x), 24-hr post-dive (x), & 72-hr post-dive (x) for the dive week. Neuromuscular activation percent change by day (right graph). O2 group (x) and Air group (x) for percent change. “ ■ ” = pre/post-WI main effect (p<0.05). “ ■ ” = day main effect (p<0.05).

SUMMARY OF RESULTS

• Significant decreases were seen in maximal strength performance on Day 3 (MVC knee extension: Air: -3.4%, p=0.001; O2: -4.3%, p=0.016; MVC elbow flexion: -3.5%, p=0.002 combined group result) with recovery occurring by Day 5.
• Combined group maximal IK elbow flexion and MVC strength performance decreased by 4% and 5%, respectively. throughout the DW (W1 > W2 and W5, p<0.001).
• O2 group knee extensor neuromuscular activation decreased by 10% throughout the DW and remained reduced by 14% through the 72-hr post-WI.

CONCLUSION - Consecutive, resting long-duration normoxic and hyperoxic WIs cause noticeable decrements in muscular strength performance after three days of WIs with recovery seen by 24-hr post-WI. Hyperoxic WIs cause significant reductions to neuromuscular activation in load bearing muscles. Further analyses are required to determine the mechanisms involved.

KEY REFERENCES

• Florian JP, Simmons EE, Thurston TS, Haren FJ, Shykoff BE. Human performance capabilities are reduced more after 100% oxygen dives than after dive air. MHG. 2010.

ACKNOWLEDGEMENTS

We thank the corpsmen and electronics technicians at NEDU; as well as NEDU’s technical support staff. Additionally, we are very grateful for the participation of the research subjects. This research is supported by the Office of Naval Research (ONR) Award (N000141612112) and N/A/SEA DISSEP (N00024161R02277). The opinions and assertions contained herein are those of the authors, not to be construed as official or reflecting the views of the Department of the Navy or the US Government.