



Nitrox: The Key to Reduced Fatigue or All in Your Head?

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Introduction

SCUBA diving is a popular recreational activity, with an estimated 3.145 million Americans participating (Denoble, 2016). When diving recreationally, there are two common compositions for the breathing gas inside the cylinders: Air, which has the same oxygen-to-nitrogen ratio as the atmosphere, and Enriched Air Nitrox (EAN or Nitrox), which contains more than 21% oxygen. Diving with EANx increases oxygen content while decreasing nitrogen concentration, in turn reducing nitrogen absorption during dives, allowing longer dive times, shorter surface intervals, and deeper limits on repetitive dives (Wormald, 2024). One of the main benefits of diving with Nitrox is that it slows nitrogen on-loading, allowing divers to dive longer with shorter surface intervals.

Understanding if Nitrox reduces post-dive fatigue has very important implications for both recreational and scientific diving. Divers commonly choose Enriched Air Nitrox with the expectation that it will reduce fatigue on compound dives. In scientific and commercial diving, where divers may complete multiple dives over consecutive days while performing physically and cognitively demanding tasks, reduced fatigue could improve efficiency, concentration, and overall safety. However, if breathing EANx while diving is a perceived reduction in fatigue rather than a physiological reduction in fatigue, divers should instead base gas selection on Nitrox's physiological benefits, such as slowing nitrogen unloading, lengthening dives with no-decompression limits, and increasing overall safety margins.

Among divers, there is a colloquial belief that diving with Nitrox lessens fatigue compared to diving with regular Air. However, this common anecdote lacks any statistically significant

evidence to support the claim of decreased fatigue. Conversely, there have been few studies that have shown that feelings of decreased fatigue were placebo. Scott Chapman of San Jose State University found that, “The data did not indicate reduced fatigue following EAN36 dives compared to Air dives of similar depth and duration” (Chapman, 2007, p.5). Further, Emma Ziska, a former Naut who studied the effects of EANx on post dive fatigue found that, “The implication of this conclusion is that while EAN does provide longer bottom times at deeper depths, when diving in shallow water, Air is just as preferable as EAN in terms of post-dive fatigue since there seem to be no extra benefits to EAN” (Ziska, 2019, p. 9). The purpose of this study is to determine whether the use of Enriched Air Nitrox reduces objective and subjective measures of post-dive fatigue compared to compressed Air.

Methods

Within this study, five commonly used cognitive and physiological tests were used to assess fatigue. Data collection was completed before and after two 60-foot dives using SCUBA at Hudson Grotto in Hudson, Florida. Each diving



participant dove for 30 mins 2 times a day during the study. Hudson Grotto is a one-hundred-and-forty-foot sinkhole of tannic brackish water with calm conditions. By the end of the study, a total of 120 dives were completed, yielding 30 Air and 30 Nitrox trials. A few physiological and

cognitive assessments were selected to evaluate multiple aspects of post-dive fatigue, including physical performance, attention, processing speed, executive function, and subjective workload.

Physical fatigue was measured using a timed jumping jack test, in which participants completed fifty jumping jacks as quickly as possible while maintaining proper form. This assessment provided a simple measure of physiological fatigue and physical performance before and after diving. Cognitive fatigue was evaluated using the Trail Making Test (TMT), a standardized assessment that measures cognitive capabilities by requiring participants to connect a sequence of alternating numbers and letters as quickly and accurately as possible. Reaction times were assessed using the Psychomotor Vigilance Test (PVT), in which participants selected input in a box whenever the red numbers appeared, with slower response times indicating reduced alertness. The Stroop Test measured alertness, reaction times, and mental processing capabilities by requiring participants to identify the color of displayed words while the word itself described a color, whether the color was congruent with the word or incongruent, providing an assessment of cognitive control and mental processing speed. Finally, subjective fatigue was evaluated using the NASA Task Load Index (NASA-TLX), a validated survey that measures perceived fatigue for the mental demand, physical demand, temporal demand, performance, effort, and frustration of the previous tests.

Upon arrival, the divers underwent each mental and physiological test to assess baseline fatigue, and then at the end of the day, the same tests were administered to assess the amount of fatigue gained from the two dives conducted.



Participants were given two tanks filled with the pre-determined breathing gas mixture that they would be using during both dives. All dive tanks clearly displayed the gas mixture they contained as required; therefore, to eliminate the impacts of a placebo effect, the diving tanks were covered with sleeves so participants could not tell which mixture they were using. To ensure divers

maintain proper safety measures throughout the study, each tank was analyzed by Josiah Keup, the primary investigator, Katie Cooper, the Chief Operating Officer of SCUBAnauts International, and the staff at Heroes Dive Center in Dunedin, in accordance with standard diving protocol. The randomization of the trials was determined by an online program called “Wheel of Names,” which generated the gas type (Air or Nitrox) each diver received for the day. The established, standardized dive profile was consistently safe for diving with either Air or EAN36, a breathing mixture of 36% oxygen and 64% nitrogen. The mixtures of Air and EAN36 were selected for this project because Air is the standard mix most divers use, and EAN36 is the highest oxygen concentration typically used by a recreational diver.

During the dives, participants were tasked with activities to simulate the maximum demands of a typical scientific dive, in order to stimulate nitrogen loading. During the first dive, all participants built a cube from PVC pipes,



placed simple shapes into a dodecahedron-shaped puzzle, and screwed and unscrewed hex nuts onto screws affixed to a wooden plank. For the second dive, divers alternate turns transporting twenty pounds of weight across the platform. Each buddy team was supervised by a dive professional who ensured adherence to the prescribed dive profile and standardized activities and oversaw dive safety.

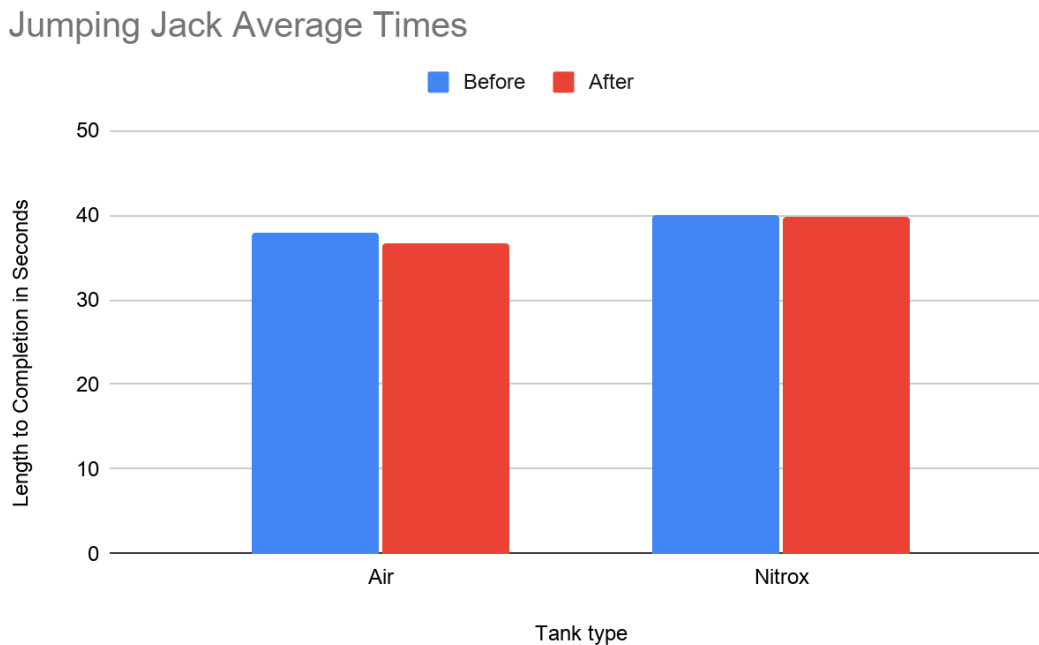
Once all dives were completed, study members repeated the cognitive and physiological tests they had completed before the first dive. The post-dive tests were all administered 15 minutes after the final dive to maximize the size of the nitrogen bubbles formed during the dive. These pre- and post-dive tests have been compared to determine whether EAN divers objectively experience less post-dive fatigue than Air divers.

Results

The total compiled data included 62 participants over 9 days, yielding 120 data points, all gathered through comprehensive pre- and post-dive mental and physiological fatigue assessments. It is important to note that during the first test date, the participants did not complete a subjective fatigue test.

Jumping jack completion times showed minimal differences between Nitrox and Air divers (Air: 37.2 s; Nitrox: 39.9 s). Participants who dove with Nitrox exhibited slightly less variation in pre- and post-dive performance (Air: -1.32 s; Nitrox: -1.37 s); however, this difference was not statistically significant ($t = -1.229$, $p = 0.225$) (Figure 1).

Figure 1: Average Jumping Jack times between Air and Nitrox before and after diving



The Trail Making Test (TMT) performance differed minimally in terms of percentage answered correctly. The difference between Air and Nitrox divers after diving was not statistically significant ($t = -0.511$, $p = 0.611$) (Figure 2). Likewise, the time required to complete the TMT showed only a negligible difference between breathing gas conditions and was not statistically significant ($t = -0.046$, $p = 0.964$) (Figure 3).

Figure 2: Average Percentage of Correct answers for the Trail Making Test between Air and Nitrox, before and after diving

TMT Percentage Correct Averages

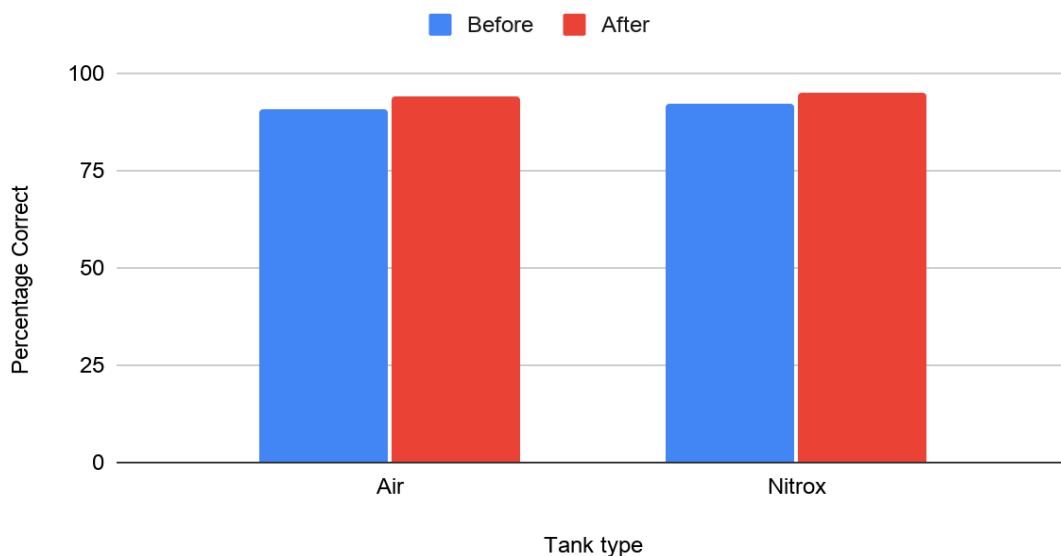
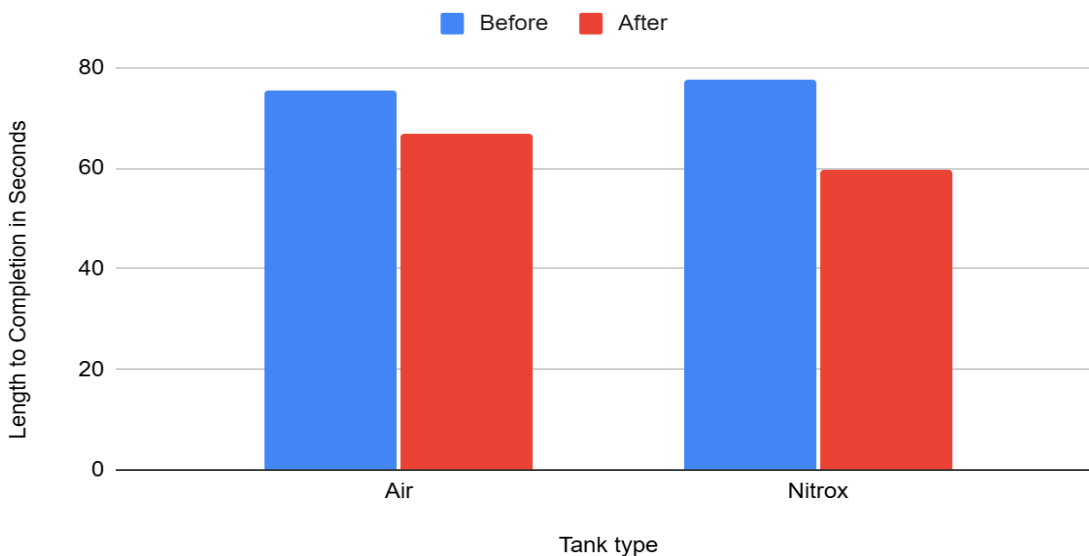


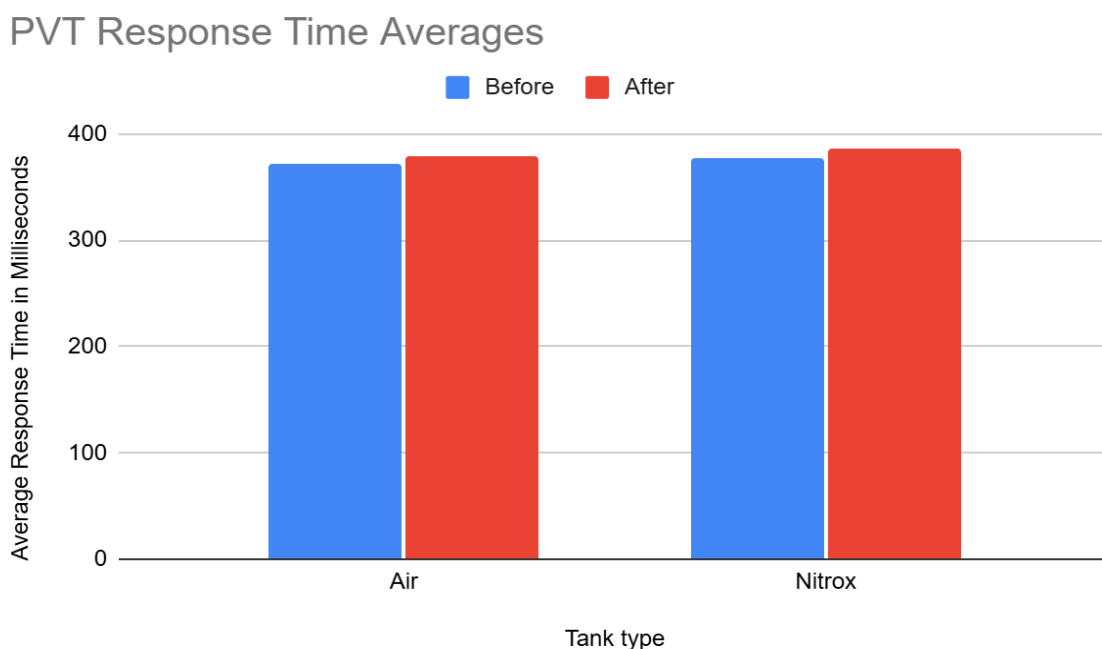
Figure 3: Average amount of time to completion on the Trail Making Test between Air and Nitrox, before and after diving

TMT Average Time to Completion



Psychomotor Vigilance Test (PVT) response times did not appear to differ between gas compositions. Although the average response times were slightly lower for the Air divers, the difference between groups was not statistically significant ($t = -0.369$, $p = 0.714$) (Figure 4).

Figure 4: Average response time on the Psychomotor Vigilance Test between Air and Nitrox, before and after diving



The Stroop trials showed no substantial variation in response times between congruent and incongruent conditions. For the congruent Stroop trials, the difference between Air and Nitrox divers approached but did not reach statistical significance ($t = -1.707$, $p = 0.094$). Likewise, incongruent Stroop response times did not differ significantly between breathing gas conditions ($t = 0.848$, $p = 0.400$) (Figures 5–6).

Figure 5: Average response times for congruent colors on the Stroop Test between Air and Nitrox, before and after diving.

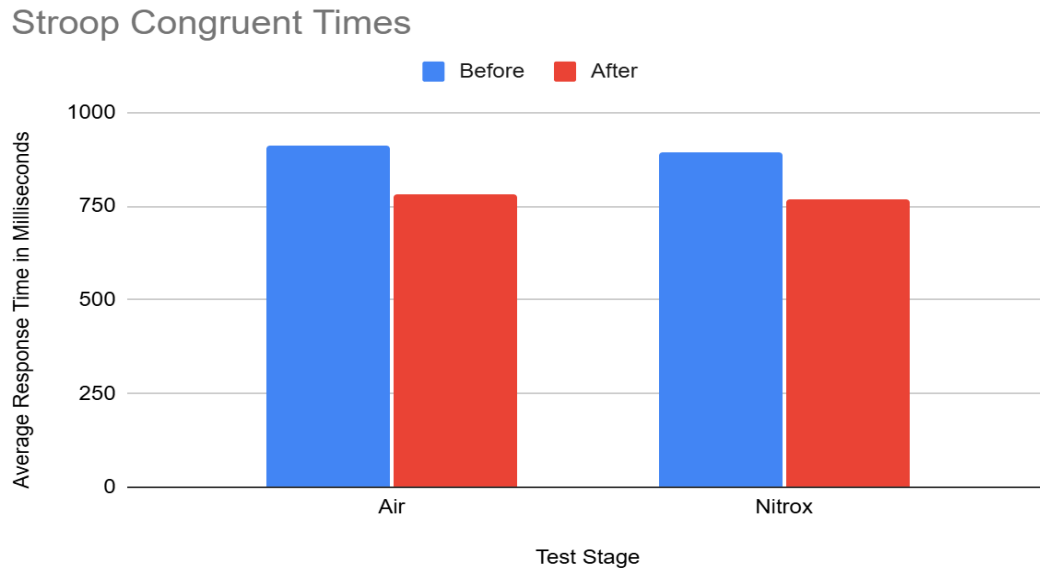
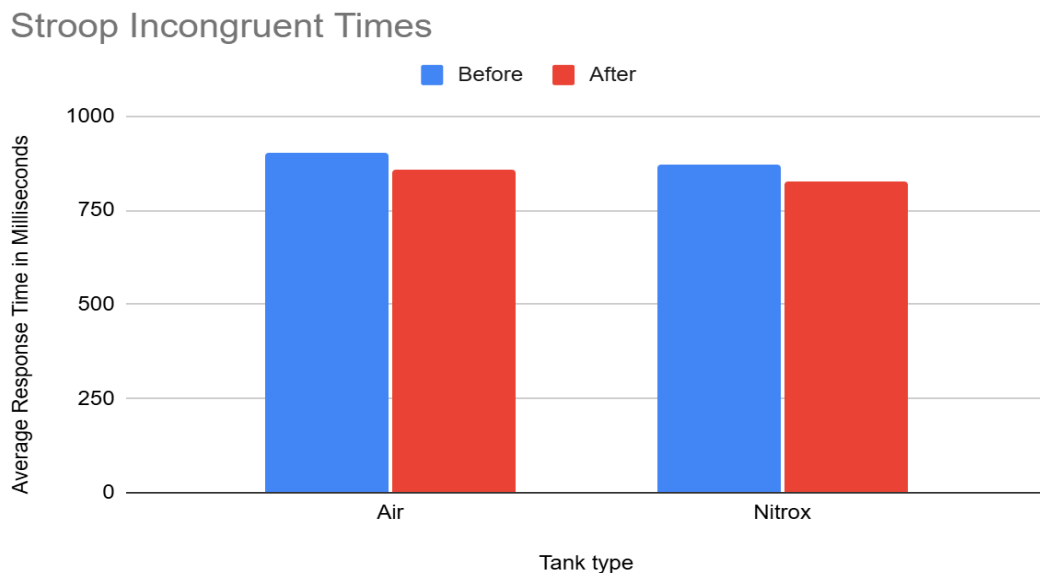


Figure 6: Average response times for incongruent colors on the Stroop Test between Air and Nitrox, before and after diving.



Interestingly, subjective fatigue, assessed by the NASA Task Load Index, showed a lower perceived task demand following Air dives. Comparisons between gas conditions showed statistically significant differences for temporal demand ($t = -2.538$, $p = 0.014$) and effort ($t = -2.802$, $p = 0.007$), with participants in the Air condition reporting lower perceived temporal demand and effort than those using Nitrox. However, no statistical significance was reported for the tests assessing mental demand ($p = 0.159$), physical demand ($p = 0.353$), performance ($p = 0.133$), or frustration ($p = 0.278$) (Figure 7-8).

Figure 7: The Average Response to the NASA Task Load Index for Air, before and after diving

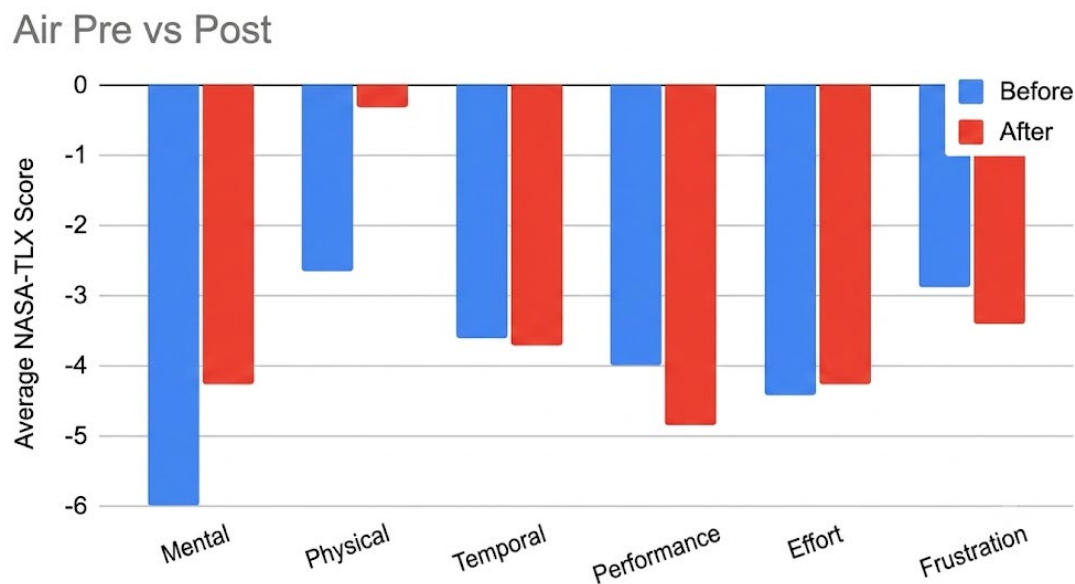
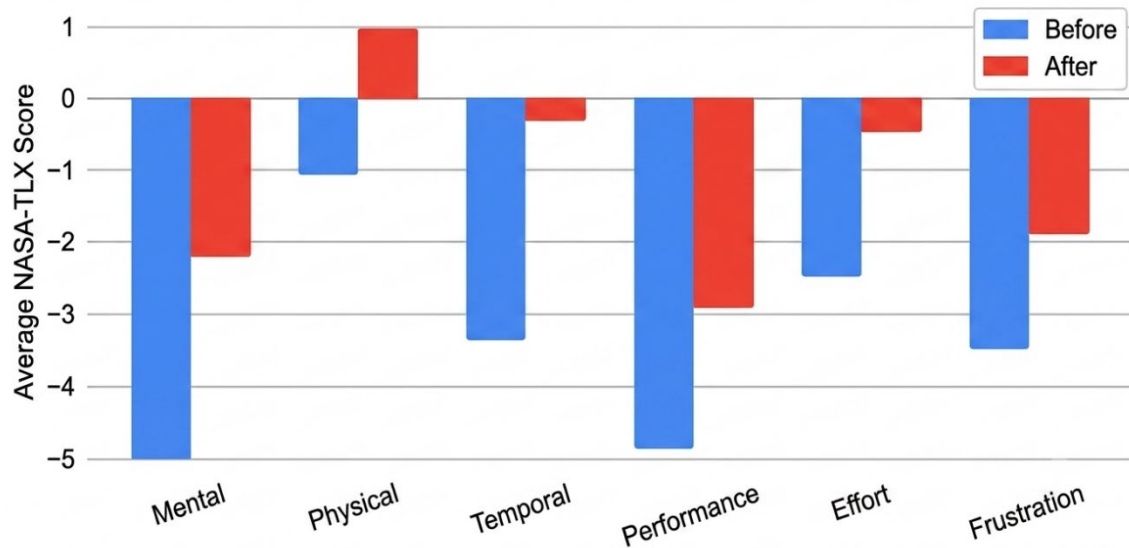


Figure 8: The Average Response to the NASA Task Load Index for Nitrox, before and after diving

Nitrox Pre vs Post



Discussion

Although it is widely believed within the diving community that Nitrox decreases post-dive fatigue, the results of this study did not provide statistically significant evidence to support this prevalent idea. Across the cognitive and physiological tests and subjective fatigue assessments, all results showed minimal variation between dives conducted with Enriched Air Nitrox and those conducted with Air.

The physiological fatigue test, measured by how long it takes the subject to complete fifty jumping jacks, showed limited change between the Air and Nitrox groups (Figure 1). While Nitrox divers exhibited marginally smaller changes in pre- and post-dive performance, as can be seen in the jumping jack test, and the Stroop test. The variation is not statistically significant enough to suggest that the oxygen composition influenced physical fatigue under the conditions tested.

Similarly, the cognitive tests, including the Trail Making Test (TMT), Psychomotor Vigilance Test (PVT), and Stroop test, showed minimal variation in results, suggesting that no improvement in mental fatigue was achieved with Nitrox. Response accuracy and reaction times remained relatively consistent across both breathing gas conditions, indicating that increased oxygen concentration did not substantially improve cognitive performance or reduce mental fatigue following repetitive dives. Interestingly, the test speed shown on the TMT time-to-completion chart (Figure 3) shows a smaller gap for the Air divers. The difference, however, is not significant.

The results for the subjective fatigue assessment (Figure 7) show that air divers report feeling significantly less fatigue after the dives than the EANx divers. Participants who dove with Air generally reported lower mental and physical demands, effort, and frustration following completion of their tests. These findings are notable as many divers anecdotally describe feeling more alert and less fatigued after Nitrox dives. This suggests the potential impact that the placebo effect has on divers in the broader diving community, which seems to dictate that pre-dive expectations of reduced fatigue result in reduced fatigue. The discrepancy between diver perception and measurable outcomes supports previous research suggesting that the perceived benefits of Nitrox may be influenced, at least partially, by placebo effects (Chapman, 2007; Ziska, 2019). The primary reason Air divers felt better is likely that they still assumed they received a Nitrox gas mixture.

The findings of this study contribute to the growing body of research suggesting that Nitrox does not significantly reduce post-dive fatigue under diving conditions. Despite not reducing

fatigue, Nitrox remains a valuable tool in recreational and scientific diving operations, as it still reduces nitrogen loading, allowing for longer dive times.

It is important to address the study's limitations. The study focused on short-term fatigue immediately following repetitive dives and did not evaluate delayed fatigue symptoms that may occur several hours after diving. Additionally, the absence of subjective fatigue data from the first testing day reduced the completeness of the NASA-TLX analysis.

Future research could expand upon this study in several ways. Researchers could investigate more demanding dive profiles involving greater depths, longer bottom times, or multiple repetitive dives over several consecutive days, as these conditions may produce greater nitrogen loading and potentially amplify differences between gas mixtures. Future studies could also incorporate more physiological fatigue tests. Studies that test fatigue several hours after diving may also provide further insight into the relationship between Nitrox use and diver recovery.

Conclusion

Overall, the findings of this investigation suggest that Enriched Air Nitrox does not significantly reduce physical, cognitive, or subjective post-dive fatigue compared to compressed Air.

Therefore, the hypothesis that the use of Nitrox blends will reduce objective and subjective measures of fatigue is unsupported by the results of this study. While Nitrox remains advantageous for extending dive safety margins and reducing nitrogen exposure, its reputation as a fatigue-reducing breathing gas may be more strongly rooted in diver perception than measurable physiological effect.

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