Mind Under Pressure: Assessing the Impact of Recreational Diving Gases on Scuba Divers' Neurocognitive Performance

Sarah Crawford MD, DABIM, MSc, DMT | Kristi Ray DO | Keith Van Meter MD

Introduction

Enriched air nitrox (EANx) has established itself as a primary tool for divers to extend their no decompression limits. While nitrox exposes divers to less nitrogen, which may reduce the chance of developing inert gas narcosis or decompression illness, few studies have examined the anecdotal neurocognitive benefits of improved mental clarity and reduced fatigue.

Overall, nitrox may have the potential to improve diving safety based on improved neurocognitive performance. This is important for divers who for example have a high task load underwater. Instructors teaching classes or students actively engaged in learning new skills may benefit from enhanced mental clarity.

Nitrox does however introduce important considerations for the diver. The higher oxygen partial pressures must be kept within limits to avoid oxygen toxicity. The dive community recognizes a PPO_2 of 1.4 ATA to be the maximum exposure allowed for the working portion of most dives, whether they are sport or technical dives. An exposure as high as 1.6 is acceptable for the decompression phase of a technical dive. Divers beyond this limit have the potential for immediate oxygen toxicity. This lends to a discussion on maximum operating depth, central nervous system oxygen toxicity, and pulmonary oxygen toxicity.

Figure 1: LSU's Diving Medicine Research Team gearing up for a research dive.
Figure 2: Entrance to Blue Grotto Dive Resort.

Objectives & Hypothesis

The purpose of this pilot study was to evaluate the effects of 4 recreational diving gases (air, EANx28, EANx32, and EANx36) on neurocognitive performance at isobaric conditions (60 FSW). Based on a thorough review of current literature, these 4 gases have not been utilized in any study to assess overall neurocognitive performance and individual cognitive domains. It was hypothesized that breathing a higher percentage of oxygen would be associated with a higher score on the Montreal Cognitive Assessment (MoCA).

Figure 3: LSU's Diving Medicine Research Team geared up for a research dive as part of "Mind Under Pressure".

Methods

- Research took place at Blue Grotto Dive Resort, a freshwater spring and cavern that maintains a year-round temperature of 72°F (22°C).

Figure 3: Layout of Blue Grotto Dive Resort in Williston, Florida.

- 20 divers were randomized to 1 of 4 groups (air, EANx28, EANx32, EANx36), with 5 divers assigned to each group.
- Divers were provided with an underwater slate/pencil containing the MoCA, a rapid screening test for mild cognitive dysfunction. It assessed several cognitive domains and took the divers ~10 minutes to complete. The total possible score was 30 and scores ranging 26-30 were considered within the range for normal cognitive function. A score of 18-25 indicated mild cognitive impairment; 10-17 moderate cognitive impairment; 0-9 severe cognitive impairment. Divers completed their test at 60 FSW.
- The principal investigator monitored completion of the test and safety divers were available for assistance.
- The primary outcome was the overall MoCA score. Secondary outcomes were the individual cognitive domain scores.
- Inclusion criteria: Divers aged 21-65, English-speaking.
- Demographic data was collected including age, sex, highest level of education. Diving history was documented including highest level of diving certification, number of lifetime dives, and years of active diving.

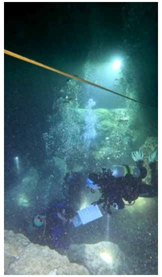
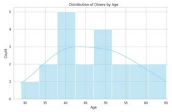
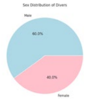


Figure 4: Dr. Crawford hands out the neurocognitive assessment to volunteer divers.

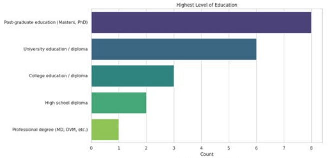
Diver Information

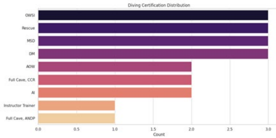




Age Profile: The divers ranged in age from 29-65 years old. The age distribution showed a significant concentration of divers in their 40s and 50s.
Sex Distribution: The group consisted of 12 males (60%) and 8 females (40%).

Diver Information





Education Level: The divers were highly educated, with the majority holding either a university education or post-graduate degree (Masters, PhD).
Diving Certification: Experience levels varied widely, ranging from Advanced Open Water (AOW) to professional and technical certifications such as Instructor Trainer, Full Cave, and CCR (Closed Circuit Rebreather).
Diving Experience:
Years Active: Divers had between 2 and 47 years of active diving experience.
Lifetime Dives: The number of lifetime dives ranged from 80 to over 4100, indicating a mix of recreational and very experienced professional and technical divers.

Results

11 divers had normal cognition and 9 had mild cognitive impairment (1 air, 3 EANx28, 2 EANx32, 3 EANx36).

Lowest Scores

The lowest score was 18 suggesting a higher end of mild cognitive impairment. This score was obtained by 1 air diver and 1 EANx36 diver. The air diver was a 52 yo M AOW diver with a college education and 80 dives in 25 years. This particular diver held the lowest level of diving and had the least diving experience of any participant with 80 lifetime dives. He was also one of the older divers at age 52. His worst cognitive domains were language, delayed recall, and orientation. Of note, he had recently purchased new gear and was unfamiliar with his equipment. He had significant difficulty with task loading and was consistently checking his pressure gauge and clearing his mask due to ongoing leakage. This lack of experience and task-loading challenge likely led to his poor score.

The EANx36 diver who scored 18 was a 42 yo M DM with a high school education and 320 dives in 28 years. This diver held a middle level of dive education and had very few dives for a 28 year diving history. He had a high school education and so 1 point was added to his raw score of 17/30. His worst domains were abstraction, visuospatial / executive, and orientation. Noted to have a difficult time with task loading, he was seen frequently checking his gauges and looking around at other test takers. Of note, this diver left the orientation section blank, a portion worth 6 points. It is unknown why this diver chose not to complete this section - he may have missed it due to stress or chose not to complete it.

Figure 5: Dr. Crawford briefs divers on the neurocognitive assessment.

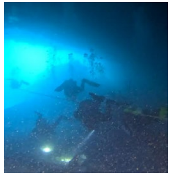


Figure 6: Dr. Crawford leads divers out of the cavern.

Highest Scores

The highest score was 29/30 and was obtained by a 38 yo M full cave/CCR diver with a post-graduate education and 601 dives in 10 years. This diver was the most experienced diver of the study holding the highest level of certification. As a highly experienced technical diver, he likely had no difficulty with task loading and possible adaptation to the effects of nitrogen.

Discussion

Since this pilot study only involved 20 divers, there was not sufficient statistical power to draw definitive conclusions. As such, the focus of the study shifted from "proving" a hypothesis to describing patterns, assessing feasibility, and estimating effect sizes for future research. Several limitations to the pilot study were identified, including:

1) Lack of Statistical Significance
2) Lack of Blinding
3) Age Distribution
4) Gender Differences
5) Education Level
6) Previous Dive History
7) Temperature
8) Nitrogen Tolerance

The findings of this pilot study were not consistent with the hypothesis that divers breathing a higher percentage of oxygen will score higher on their neurocognitive assessment. That being said, this pilot study was underpowered and therefore did not have enough participants to draw statistical conclusions. As such, this hypothesis may very well be proven correct once this study is conducted on a larger scale. The patterns detected in this pilot study will assist in the future development of a larger-scaled neurocognitive research study on scuba divers.

Conclusion

While primarily adopted to extend no decompression limits, divers also use nitrox to dive with a reduced fraction of nitrogen and therefore limit nitrogen narcosis. It is well established that nitrogen narcosis impedes neurocognitive performance at depth, and so breathing a gas mix higher in oxygen may be protective for cognitive function. As no previous studies have compared these gases' impact on neurocognitive performance, this research has the potential to provide important information to divers regarding gas choice.

Although this pilot study was underpowered with no statistical significance, patterns were described, outcomes assessed, and feasibility of a future and larger-scaled neurocognitive study were addressed. This project provided valuable feedback to the principal investigator who will be conducting this project on a larger scale in the near future. The future study at 80 FSW will involve 100 volunteer divers 25 randomly assigned to each of the 4 groups. If the hypothesis is proven correct that breathing a higher percentage of oxygen is associated with higher neurocognitive test scores, it can be extrapolated that nitrox blends containing a higher percentage of oxygen may allow divers to more efficiently manage tasks underwater. This is especially important on dives where task loading may be significant. Overall, nitrox may have the potential to improve diving safety based on enhanced mental clarity and the MoCA was found to be a viable tool for assessing scuba divers' neurocognitive function in the field.

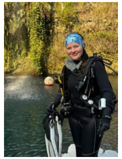


Figure 7: Dr. Crawford wraps up a research dive at Blue Grotto.

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