World as it is

Drinker driver flyer diver

Gerard Laden[1], Bruce Mathew[1]

[1] *Clinical Hyperbaric Facility, Hull and East Riding Hospital, Anlaby, UK*

Corresponding author: *Gerard Laden. Clinical Hyperbaric Facility, Hull and East Riding Hospital, Anlaby, UK*
ORCID: *0009-0008-0820-8291*
gerard.laden@mimirmarine.com

Keywords
Diving; Inert gas; Narcosis; Nitrogen; Scuba

Abstract

(Laden G, Mathew B. Drinker driver flyer diver. Diving and Hyperbaric Medicine. 2024 30 June;54(2):137–139. doi: 10.28920/dhm54.2.137-139. PMID: 38870957.)
Blood alcohol concentrations above defined levels are detrimental to cognitive performance. Empirical and published evidence suggest that nitrogen narcosis is analogous to alcohol intoxication with both impairing prefrontal cortex function. Nitrogen narcosis is also known to have been a factor in fatal accidents. To examine the effects of nitrogen narcosis, a recent publication used the Iowa Gambling Task tool, to simulate dynamic real-life risky decision-making behaviour. If the reported outcomes are corroborated in larger rigorously designed studies it is likely to provide further evidence that divers may well experience the negative effects of a 'narcotic agent', even at relatively shallow depths. These deleterious effects may occur regardless of diving experience, aptitude or professional status. In 1872, English law made it an offence to be 'drunk' whilst in charge of horses, carriages, cattle and steam engines. Understanding the danger was easy, establishing who is 'drunk' in the eyes of the court required a legal definition. Driving above a 'legal limit' for alcohol was made illegal in the United Kingdom in 1967. The limit was set at 80 milligrams of alcohol per 100 millilitres of blood. It took just short of one hundred years to get from first introducing a restriction to specific activities, whilst under the influence of alcohol, to having a clear and well-defined enforceable law. The question surely is whether our modern society will tolerate another century before legally defining safe parameters for nitrogen narcosis?

Introduction

It is widely accepted that a blood alcohol concentration above defined levels is detrimental to cognitive performance. Many countries have introduced a statutory upper limit of blood alcohol concentration for driving and a 'lower' upper limit for selected occupations for example: pilots, cabin crew, air traffic controllers and train drivers. Diving whilst under the influence of alcohol is also a bad idea.[1]

Empirical and published evidence suggest that nitrogen narcosis is analogous to alcohol intoxication with both states impairing prefrontal cortex function.[2] These deleterious effects may occur regardless of diving experience, aptitude or professional status. Multiple diving agencies have reported nitrogen narcosis as a contributing factor in fatal accidents.[3–6]

The medical literature is replete with information about the potential physiological and pathological consequences of breathing gases at increased partial pressures.[7] This includes nitrogen, oxygen, carbon dioxide, carbon monoxide and even helium. Examining the effect of nitrogen narcosis on divers is certainly not new. The literature contains many studies including those examining the effect at pressures less than thirty metres of sea water (msw) and a randomised controlled trial examining air breathing at 30 msw compared to a twenty percent oxygen-helium mixture and oxygen enriched air breathing.[8,9] Most studies to-date are more qualitative than quantitative (often involving arithmetic and reaction times and the self-reporting by participants) all require interpretation to appreciate their cognitive (i.e., decision-making) significance in the divers actual environment.[4] One study recently explored a quantitative EEG metric to measure the effects of nitrogen narcosis.[10] If the approach described can be operationally developed it would have the important potential to inform the diver in real time of early cognitive impairment. Their proposed cognitive monitoring system has far-reaching applications, one example being pilots when artificial intelligence or ground crew could take over in the event of objective evidence of cognitive compromise, another is deep recreation diving.

Narcosis in diving

In the December 2023 issue of *Diving and Hyperbaric Medicine*, Pauliina Ahti and Jan Wikgren, report using the well-known Iowa gambling task (IGT) research tool as a psychological assessment of diver's decision-making whilst

they were breathing air at two different depths: 5 and 30 metres of fresh water (mfw).[11] They noted a statistically significant difference in the IGT scores with the diver at 30 mfw revealing "*impaired cognitive function*" (i.e., taking 'riskier' decisions) than the divers at 5 mfw. Considering other variables, they attribute the difference to nitrogen narcosis. What is different in the Ahti, paper is that the cognitive assessment tool is well known and accepted and can be used to simulate dynamic real-life 'decision-making' and particularly 'risky' decision-making behaviour.[12,13] When examining risk and decision making an individual's motivational system needs also consideration, the Ahti study controlled for this influence.[14,15]

Accepting that the Ahti study involved small numbers, if the reported outcomes are corroborated in larger rigorously designed studies it is likely to provide further evidence that divers may well experience the negative effects of a 'narcotic agent', even at relatively shallow depths and introduce something of a regulatory conundrum for the diving industry ranging from the sport scuba diving instructor through to the offshore oil and gas professional and the military. The Ahti study appears to provide reliable quantitative data concerning decision-making and risk taking which indicates that even at shallow depths, a 'professional' diver undertaking paid work may well be under the influence of a 'narcotic' agent, that measurably, detrimentally impairs decision making.

Different organisations offer different advice concerning the risks of nitrogen narcosis, with recommended maximum depths for air diving typically ranging from 20 to 40 msw. The United Kingdom Health and Safety Executive, stipulates the maximum depth for breathing compressed air or other mixtures of oxygen and nitrogen as 50 msw. The effect of nitrogen as a narcotic agent at depth varies widely with notable between-and within-individual sensitivity. This may also be the case with the diver's subjective versus objective appreciation of narcosis. Just as you would not ask a person under the influence of alcohol to complete a work task 'risk assessment', so too the diver at depth, suffering from the effects of nitrogen narcosis, is compromised.

Alcohol intoxication vs nitrogen narcosis

Returning to the comparison of nitrogen narcosis and alcohol intoxication. The question often asked is whether self-regulation is adequate.[1] Surely, we already have the answer? Eventually government regulatory authorities, such as the United Kingdom's Health and Safety Executive are going to have to address the 'nitrogen narcosis' question possibly by defining what is and is not acceptable in respect of being under the influence of a narcotic agent in the workplace. Nitrox may help, however unlike alcohol consumption abstinence from nitrogen as depth increases is often not a practical option.

In many countries there are no employment laws concerning the consumption of alcohol at work. Nevertheless, all employers have a legal duty to ensure the health, safety and welfare of their employees (including the military). In other words, if you knowingly allow an employee under the influence of alcohol, drugs or a known narcotic agent to continue working, and this places the employee or others at risk, you could be liable. Moreover, the underwriters of 'employer's liability' insurance are likely to want to better understand the risk they are being asked to underwrite. Scuba diving was pioneered in the early 1940's. In 1984 Wilmshurst first reported a fatality resulting from immersion pulmonary oedema (IPO) and by 1989 had publishing a case series.[16] Forty years on IPO is now considered the most common cause of death in divers with many past cases having arguably wrongly been classified as drowning. Similarly, one is prompted to ask the question as to how many past diving deaths should really have been considered due to nitrogen narcosis causing poor or 'risky' decision making?

A 'duty of care' is generally defined as 'to take all measures that are reasonable in the circumstances to ensure participants will be safe in participating in the relevant activity'. Sports diving service providers generally assume that divers accept the risks involved. The legal maxim is "*Volenti non fit injuria*", meaning "*to a willing person, it is not a wrong*". That is, by diving one is accepting an assumption of risk.

As is often the case following any serious accident, a signed liability waiver or release statement is likely to be challenged as a defence. In any event being willing to accept a risk raises another conundrum. Is there any possibility of obtaining 'informed' consent from a diver? For the depth-time profiles common in air diving, it appears that defining an individual's susceptibility and response to nitrogen as a consequence of descent to depth may be similar to the wide 'within' and 'between' subjects' variability of bubble production from ascending. A random probability distribution that can be analysed statistically but may not be accurately predicted.[17]

One of the earliest known reports of what we now know to be nitrogen narcosis was by the French physician Colladon in 1826, however it wasn't until 1935 just over 100 years later when Behnke identified nitrogen narcosis as the likely cause.[18,19] In 1872, English law made it an offence to be 'drunk' whilst in charge of horses, carriages, cattle and steam engines. Understanding the danger was easy but establishing who is 'drunk' in the eyes of the court, required legal definition. Driving above a legal limit for alcohol was only made illegal in the United Kingdom by The Road Safety Act of 1967. The limit was initially set at 80 milligrams of alcohol per 100 millilitres of blood or a 0.08% blood alcohol concentration. It took just short of one hundred years to get from first introducing a restriction to specific activities whilst under the influence of alcohol to having a clear and well-defined enforceable law. The problem with conundrums is that they are often hard to resolve. Maximum safe depths

for air diving of: 20, 30, 40 and 50 metres of sea water, have all been advocated in academic publications, by training organisations and government agencies for the mitigation of nitrogen narcosis. Clarity of thinking surrounding nitrogen narcosis is needed and will come from challenging the certainty of the advice being offered.

References

1 Sheldrake S, Pollock NW. Alcohol and diving. In: Steller D, Lobel L, editors. Diving for Science 2012. Proceedings of the American Academy of Underwater Sciences 31st Symposium. Dauphin Island (AL): AAUS; 2012.

2 Hobbs M. Subjective and behavioural responses to nitrogen narcosis and alcohol. Undersea Hyperb Med. 2008;35:175–84. PMID: 18619113.

3 Tillmans F. DAN Annual Diving Report. 2020 ed. A report on 2018 diving fatalities, injuries, and incidents. Durham (NC): Divers Alert Network; 2021. [cited 2023 Feb 16]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK582514/.

4 Clark JE. Moving in extreme environments: inert gas narcosis and underwater activities. Extrem Physiol Med. 2015;4:1. doi: 10.11186/s13728-014-0020-7. PMID: 25713701. PMCID: PMC4337274.

5 Michalodimitrakis E, Patsalis A. Nitrogen narcosis and alcohol consumption – a scuba diving fatality. J Forensic Sci. 1987;32:1095–7. PMID: 3612064.

6 Vann R, Lang M. Recreational diving fatalities. Undersea Hyperbaric Med. 2011;38:257–60. PMID: 21877554.

7 Edge CJ, Wilmshurst PT. The pathophysiology of diving diseases. BJA Educ. 2021;21(9):343–8. doi: 10.1016/j.bjae.2021.05.003. PMID: 34447581. PMCID: PMC8377235.

8 Paulton EC, Catton MJ, Carpenter A. Efficiency at sorting cards in compressed air. Brit J Industry Med. 1964;21:242. doi: 10.1136/oem.21.3.242. PMID: 14180485. PMCID: PMC1038362.

9 Bennett PB, Poulton EC, Carpenter A, Catton MJ. Efficiency at sorting cards in air and a 20 per cent oxygen-helium mixture at depths down to 100 feet and in enriched air. Ergonomics. 1967;10:53–62. doi: 10.1080/00140136708930839. PMID: 6036474.

10 Vrijdag XCE, van Waart H, Pullon RM, Sames C, Mitchell SJ, Sleigh JW. EEG functional connectivity is sensitive for nitrogen narcosis at 608 kPa. Scientific Reports. 2022;12(1):4880. doi: 10.1038/s41598-022-08869-8. PMID: 35318392. PMCID: PMC8940999.

11 Ahti PA, Wikgren J. Rapture of the deep: gas narcosis may impair decision-making in scuba divers. Diving Hyperb Med. 2023;53:306–312. doi:10.28920/dhm53.4.306-312. PMID: 38091589. PMCID: PMC10944662.

12 Chiu YC, Huang JT, Duann JR, Lin CH. Editorial: twenty years after the Iowa gambling task: rationality, emotion, and decision-making. 2017;8:2353. Front Psychol. doi: 10.3389/fpsyg.2017.02353. PMID: 29422876. PMCID: PMC5788943.

13 Buelow MT, Suhr JA. Construct validity of the Iowa gambling task. Neuropsychol Rev. 2009;19:102–14. doi: 10.1007/s11065-009-9083-4. PMID: 19194801.

14 Biersner RJ, Hall DA, Linaweaver PG, Neuman TS. Diving experience and emotional factors related to the psychomotor effects of nitrogen narcosis. Aviat Space Environ Med. 1978;49:959–62. PMID: 678246.

15 Löfdahl P, Andersson D, Bennett M. Nitrogen narcosis and emotional processing during compressed air breathing. Aviat Space Environ Med. 2013;84:17–21. doi: 10.3357/ASEM.3277.2013. PMID: 23304994.

16 Wilmshurst PT, Nuri M, Crowther A, Webb-Peplow MM. Cold-induced pulmonary oedema in scuba divers and swimmers and subsequent development of hypertension. Lancet. 1989;1:62–65. doi: 10.1016/s0140-6736(89)91426-8. PMID: 2562880.

17 Doolette DJ, Murphy FG. Within-diver variability in venous gas emboli (VGE) following repeated dives. Diving Hyperb Med. 2023;53:333–9. doi: 10.28920/dhm53.4.333-339. PMID: 38091593. PMCID: PMC10944664.

18 Unsworth IP. Inert gas narcosis-an introduction. Postgrad Med J. 1966;42:378–85.

19 Behnke AR. Thomson RM, Motley EP. Psychological affects from breathing air at 4 atmospheres pressure. Am J Physiol. 1935;112:554–8.

Conflicts of interest and funding: nil

Submitted: 22 February 2024
Accepted after revision: 7 May 2024

Copyright: This article is the copyright of the authors who grant *Diving and Hyperbaric Medicine* a non-exclusive licence to publish the article in electronic and other forms.