Predicted nitrogen tensions during repeated breath-hold diving in humans

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Introduction

Despite increasing interest in breath-hold diving, limited research has been conducted to investigate the potential risk of decompression sickness (DCS). While repetitive breath-hold dives to 15–20m have been reported to cause DCS in humans (Paulev, 1965, 1967), no research has attempted to improve safety or to predict safe limits for this type of activity. We used a previously published mathematical model to predict N_2 tensions (PN_2) during hypothetical breath-hold dives in a human. Our objective is to investigate possible PN_2 levels during breath-hold diving and to provide simple guidelines to improve safety during breath-hold diving.

Objective

1. Determine approximate levels of N_2 in human tissues and blood during repeated shallow and single deep dives.
2. From the results, propose simple guidelines that could reduce the risk of decompression sickness.

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Methods

- We used a previously published model that estimates N_2 tension (PN_2, ATA) in mixed venous blood and 4 tissues (central circulation [heart, liver and kidney], muscle, brain, fat) during breath-hold diving (Fahlman et al., 2006).
- We assumed a 70 kg man with a cardiac output of 6 l · min^{-1} and where central circulation, muscle, brain, fat and blood each were 3%, 74%, 2% and 15% and 6% of the body mass.
- 2 dive profiles were used;
  - 1) 30 repeated dives to 4 ATA (30 m, 98 ft) with a dive duration (DD) of 150 sec and for three different surface intervals durations (SI, 90, 150 or 300 sec).
  - 2) A single dive to 9 ATA (80 m, 262 ft) with a DD of 210 sec.
- We assumed that while submerged, the diver experienced a 50% reduction in cardiac output.
- The proportion of the cardiac output to each tissue was 35% to the central circulation, 35% to muscle, 20% to brain and 10% to fat while at the surface. While diving, the same values were 35%, 30%, 30% and 5%.

Results

-Maximum venous PN2 during 30 repeated dives to 30 m was 1.44 ATA for a SI of 300 sec and 1.69 ATA for a SI of 90 sec (Fig. 1).

-For repeated dives to 30 m, venous PN2 during the first and sixth dive reached, respectively, 88% and 97% of the maximum estimated venous PN2 during the entire series (Data not shown).

-Maximum venous PN_2 during a single deep dive was 3.0 ATA, or 310% higher than the surface equilibrium value (0.74 ATA, Fig. 2).

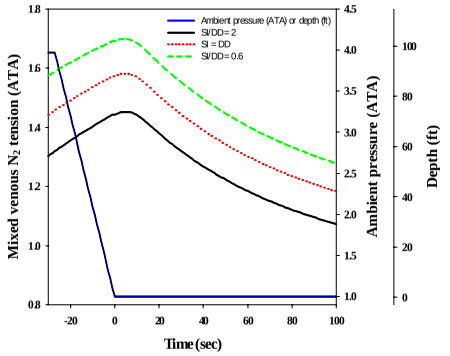

Figure 1. Mixed venous PN2 following the last dive in a repeated dive series to 30 m (98 ft).

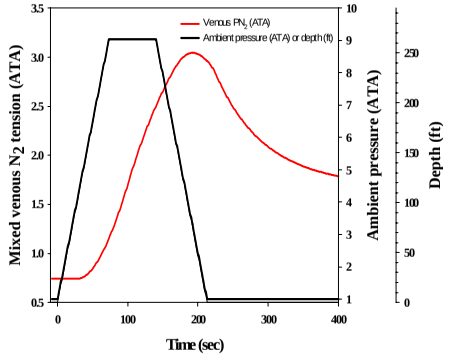

Figure 2. Mixed venous PN2 following a single dive to 80 m (262 ft).

Conclusions

-Our simulations suggest that single deep or repeated shallow breath-hold dives can result in high mixed venous N_2 tensions that could possibly lead to DCS.

-A simple way to reduce excessive PN_2 and the risk of DCS symptoms is to have an SI exceeding DI by at least 2 times.

References

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