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## Human Sleep Physiology

# Sleep patterns during 30-m nitrox saturation dives and in a confined atmospheric environment

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**Abstract** Sleep patterns during saturation dives equivalent to a 30-m depth (pressurized condition) and habitation in a confined environment at 1 atm absolute pressure (non-pressurized condition) were studied to determine the effects of environmental pressure. Eight inexperienced divers experienced the pressurized condition of the saturation dives, and nine healthy subjects experienced the non-pressurized condition. Standard polysomnographs were recorded for 262 nights. For both conditions, reductions in total sleep time accompanied by lengthening in sleep latency and reduction in sleep efficiency were observed from the latter part of the experiments through to the recovery periods. These findings suggest that changes were related to psychological and physiological stresses caused by long stays in a confined environment and not by the environmental pressure.

**Key words** 30-m nitrox saturation dives, confined 1 atm absolute environment, psychological and physiological stress, sleep polysomnography.

## INTRODUCTION

A previous study of simulated 30-m $N_2$-$O_2$ saturation dives has indicated that a decrease in total sleep time is accompanied by an increase in sleep latency and a decrease in sleep efficiency for the period commencing from the 30-m depth simulation period (pressurized period) through to the post-dive period.[1] However, it was impossible to know whether these changes were the result of the environmental pressure itself or whether they were simply due to the psychological effects of spending long periods in a confined environment. The present study sought to examine the effects of environmental pressure by comparing a pressurized environment with a non-pressurized environment in order to determine which factors affect sleep parameters in a simulated saturation dive experiment.

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## SUBJECTS AND METHOD

Both experiments were conducted using a dry chamber of the dive simulator installed at the Japan Marine Science and Technology Center, Yokosuka, Japan.

The simulated 30-m $N_2$-$O_2$ saturation dive (pressurized condition) was conducted on four different occasions under the same conditions, and the confined environment experiment at 1 atm absolute conditions (non-pressurized condition) was conducted twice. The eight subjects who experienced the pressurized condition (six males, two females; mean age 23.0 ± 2.3 years) had no previous experience of saturation diving. The nine subjects who experienced the non-pressurized condition were selected from a population of healthy male graduate students (mean age 23.5 ± 1.9 years).

The pressurized condition consisted of two observation periods, each of 4 days' duration, before and after the pressurized period; a pressurized period of 7 days; and a 2-day decompression period. The non-pressurized condition consisted of two observation periods, each of 2 days' duration, before and after the confined period; and a confined environment period lasting 10 days. Except for environmental pressure

**Table 1.** Sleep variables during pressurized and non-pressurized conditions, with significant levels

| Experimental phase | Total sleep time (min) | | Sleep efficiency index (min) | | Sleep latency (min) | |
|---|---|---|---|---|---|---|
| | Non-pressurized condition | Pressurized condition | Non-pressurized condition | Pressurized condition | Non-pressurized condition | Pressurized condition |
| Baseline nights | 409.9 ± 34.5 | 434.5 ± 20.3 | 85.4 ± 7.2 | 91.4 ± 4.2 | 43.2 ± 22.4 | 24.8 ± 18.7 |
| Experimental nights | | | | | | |
| First period | 408.9 ± 28.0 | 426.6 ± 19.3 | 85.2 ± 5.9 | 89.5 ± 4.2 | 44.6 ± 25.8 | 25.9 ± 19.1 |
| Second period | 400.1 ± 28.5 | 425.2 ± 25.1 | 83.4 ± 5.9 | 88.7 ± 5.2 | 50.4 ± 32.3 | 31.9 ± 17.8 |
| Final period | 387.1 ± 41.1 | 401.4 ± 35.5* | 80.8 ± 8.4 | 83.6 ± 7.4* | 66.3 ± 33.7* | 55.5 ± 36.6* |
| Recovery nights | 378.4 ± 41.9* | 405.5 ± 25.9* | 78.8 ± 8.7* | 84.5 ± 5.4* | 78.0 ± 48.2 | 58.5 ± 25.1* |
| ANOVA | | | | | | |
| Period | $F = 8.06$ $P < 0.001$ | | $F = 9.40$ $P < 0.001$ | | $F = 10.14$ $P < 0.001$ | |
| Condition | NS | | NS | | NS | |
| Interaction | NS | | NS | | NS | |

* Significant difference from baseline by post-hoc test $P < 0.05$.
NS, not significant.

and the days during which the experiments were held, both experiments were conducted under identical conditions for light, temperature, wake-up time (07.00 hours) and bedtime (23.00 hours).

Polysomnogram was recorded during nocturnal sleep for 262 nights, and visual scorings were conducted according to standard criteria.[2]

Means were calculated by dividing the 9-day (bottom period and decompression period) experiment at the pressurized condition and the 10-day experiment under the non-pressurized condition into three periods of 3–4 days (first period, second period, and final period). Next, means and standard deviations of the sleep parameters for five periods (baseline period, first period, second period, final period, and recovery period), including the aforementioned three periods, were calculated. Repeated ANOVA for the two factors of period and condition was used to determine significant changes in sleep variables. In addition, post-hoc tests were conducted using Tukey's HSD. The significance level was set at 5%.

## RESULTS

During the experimental periods, total sleep time, sleep efficiency, and sleep latency were found to have been affected significantly. There was no significant effect of condition or interaction. These sleep parameters of the two conditions were worse in the second and the recovery periods compared with those of the baseline periods. The post-hoc tests demonstrated that there were non-significant differences in any of the periods for the various sleep parameters of either of the conditions. (Table 1)

## DISCUSSION

Naitoh *et al*. have made polysomnogram recordings of two divers who stayed under $N_2$-$O_2$ saturation dives at depths of up to 13 m for 60 days.[3] They reported that no sleep disorders appeared during this period of living at the sea bottom. They also found that from the latter part of the final period through to the post-dive period there was generally a reduction in total sleep time accompanied by a lengthening of sleep latency and a decrease in sleep efficiency.[1] The present study obtained virtually the same results for the divers undergoing the 30-m saturation dive and for the subjects who experienced the 1 atm absolute environment.

The results suggest that these changes were more likely to have been caused by the psychological stresses and physical constraints of being subjected to small and confined spaces over a long period of time, rather than by environmental pressure.

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