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Human Sleep Physiology

Sleep patterns during 20-m nitrox saturation dives

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Abstract The sleep patterns were examined through three simulated 20-m nitrox saturation dives. The standard polysomnography of 12 divers was recorded respectively for a total of 204 nights, as were patterns of change or consistency in sleep variables. For the 11 divers in their 20s and 30s there was nothing unusual about their sleep variables. However, a reduction of total sleep time in accordance with the lengthening of sleep latency was observed. This was recognized from the latter part of the bottom period to the postdive period. This tendency was notable for the diver in his 50s. These findings suggest that the decompression environment and the psychological stress of the long-term closed environment of a hyperbaric chamber have effects on divers' sleep.

Key words Aging, nitrox saturation diving, psychological stress, sleep polysomnography.

INTRODUCTION

The recently-developed N_2–O_2 saturation diving method has come to be extensively used in place of the previously popular hyperbaric He-O_2 saturation method. In order to conduct long-term research on marine ecosystems, it is necessary to spend long periods living under water in the presence of high pressure. This project's purpose was to observe and measure the effects of human life underwater up to a depth of 50 m. Unfortunately, studies concerning polysomnography (PSG) records in N_2–O_2 saturation dives are comparatively few. Naitoh *et al.* recorded the PSG for two of four divers, who experienced 60 days of habitation under N_2–O_2 saturation dives of up to 43 feet.[1] Significantly, they reported that sleep disorders did not appear during the sea habitation. In this study we examined the influence of 20 m depth pressure N_2–O_2 saturation dives on the sleep patterns of 12 divers.

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METHOD

We examined the sleep patterns present under 20 m depth pressure for three simulated N_2–O_2 saturation dives from February 1995 to November 1996. These three simulated saturation dive experiments were performed using a chamber D_1 diving simulator at the Japan Marine Science and Technology Center. Twelve healthy male subjects were selected with an age range of 20–53 years (29.9 ± 9.0 years). Three of the subjects were inexperienced in saturation dive experiments, while the remaining nine were experienced divers who had participated in several other saturation dive experiments.

A dive profile of the experiments is given in Fig. 1. Three simulated saturation dive experiments were performed under the same conditions. In each of the three experiments, we initially monitored a 4-day predive period, then began the early compression of air to 9 m of depth pressure at the speed of 1 m/min at 10.00 h on the fifth day. From 9 m of depth pressure the compression of N_2 gas was resumed with a compression speed of 20 m/h, and reached 20 m of depth pressure at 10.48 h on the fifth day in all three experiments. The duration at 20 m of depth pressure was 187.2 h. Subsequently, decompression was started from 06.00 h in accordance with the decompression table of the US Navy Diving Manual on the 13th day.[2] After that, the divers returned to

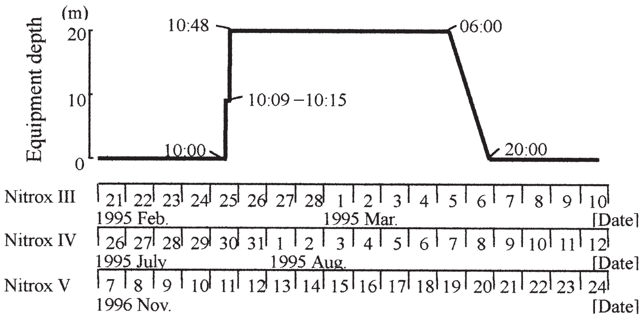

Figure 1. Profiles of 20-m nitrox saturation dive experiments.

normal atmospheric pressure at 20.00 h on the 14th day. Observation was continued for an approximately 4-day postdive period (92 h) in all three experiments after the completion of decompression. We maintained the temperature at 26°C and the humidity at 60% throughout the period of experimentation. The light–dark conditions were controlled to ensure 16 h for the light period (07.00–23.00 h) and 8 h for the dark period (23.00–07.00 h). The PSG for nocturnal sleep was recorded for a total of 204 nights. Polysomnography records were visually scored for every 20-s epoch in accordance with the criteria of Rechtschaffen and Kales.[3] Statistics were recorded for all save one diver, whose age (53 years) set him apart from the rest.

RESULTS

Table 1 shows the mean and standard deviation of each sleep variable for each experiment day for the 11 divers (the 53-year-old subject excluded). The results of the one-way ANOVA, among the experiment days, showed significant effects in sleep period time (SPT), total sleep time (TST), sleep efficiency index (SEI), and sleep latency. Sleep period time ($P < 0.01$) and TST ($P < 0.001$) were significantly shortened, in accordance with personal variations, from the seventh bottom night to the fourth postdive night. The SEI ($P < 0.001$) showed a reduction with the same tendency as the TST. Sleep latency ($P < 0.001$) significantly lengthened from the seventh bottom night to the fourth postdive night. Table 2 shows the mean percent time spent in each sleep stage. The percent of wake after sleep onset tended to increase slightly on the eighth bottom night and the decompression night. However, the the percentage of each sleep stage did not show significant effects during the entire period of experimentation.

DISCUSSION

The sleep quality of each sleep stage is similar to the PSG results of Naitoh *et al.*, who studied two divers under N_2–O_2 saturation dives up to 43 feet who did not show significant effects throughout the

Table 1. Sleep variables during N_2–O_2 saturation dives at 20 m, with significance levels

	Sleep period time (min)	Total sleep time (min)	Sleep efficiency index (%)	Sleep latency (min)
Predive night				
2nd	451.9 (21.6)	441.2 (19.6)	93.3 (2.9)	19.1 (15.9)
3rd	450.9 (14.3)	434.4 (29.3)	91.1 (5.8)	23.2 (28.2)
4th	451.9 (22.3)	446.8 (20.6)	93.8 (3.6)	24.5 (18.9)
Bottom night				
1st	459.7 (17.5)	453.4 (16.4)	95.1 (2.8)	16.9 (14.7)
2nd	445.7 (43.0)	439.6 (41.9)	92.2 (8.7)	30.8 (43.4)
3rd	450.6 (24.5)	436.6 (29.3)	92.1 (4.8)	22.8 (18.5)
4th	449.3 (29.5)	434.6 (33.6)	91.6 (5.9)	24.6 (22.4)
5th	450.7 (27.0)	432.0 (44.8)	90.5 (9.1)	26.1 (24.8)
6th	449.4 (25.7)	434.6 (34.6)	91.4 (6.6)	25.4 (21.2)
7th	437.3 (42.9)	423.0 (40.2)	88.8 (8.2)	38.7 (42.5)
8th	427.3 (43.0)	401.4 (51.7)	84.2 (10.6)	49.1 (42.5)
Decompression night	435.7 (24.0)	414.9 (27.7)	87.3 (5.2)	38.7 (22.0)
Postdive night				
1st	437.3 (28.0)	420.7 (33.6)	88.3 (7.1)	37.8 (26.2)
2nd	435.5 (28.5)	421.9 (31.7)	88.7 (6.7)	40.3 (27.2)
3rd	420.0 (37.9)	404.8 (36.1)	85.2 (7.6)	54.2 (37.4)
4th	396.6 (30.0)	390.6 (30.6)	82.1 (6.0)	76.1 (31.1)
ANOVA F ratio	2.58	2.59	2.94	15.15
P	0.01	0.001	0.001	0.001

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Table 2. Mean percent time spent in each sleep stage during N_2–O_2 saturation dives at 20 m, with significance levels

	% WASO	% Stage 1	% Stage 2	% Stage SWS	% REM
Predive night					
2nd	2.6 (2.2)	6.7 (2.4)	43.7 (4.5)	21.4 (4.2)	25.6 (3.0)
3rd	3.1 (6.0)	6.2 (1.9)	44.5 (6.2)	20.1 (4.9)	26.1 (5.1)
4th	1.1 (1.1)	5.1 (1.7)	44.5 (6.5)	21.1 (5.3)	28.2 (4.1)
Bottom night					
1st	1.4 (1.1)	5.3 (1.8)	47.7 (5.8)	19.2 (5.7)	26.4 (3.8)
2nd	1.4 (1.3)	5.8 (2.1)	43.6 (5.9)	22.0 (5.5)	27.2 (3.1)
3rd	3.2 (3.3)	7.8 (2.7)	45.4 (3.8)	17.3 (2.9)	26.3 (4.3)
4th	3.4 (2.8)	7.4 (2.8)	44.9 (5.4)	18.7 (5.0)	25.6 (5.2)
5th	4.3 (8.8)	6.3 (2.4)	44.6 (5.0)	20.0 (4.6)	24.8 (4.3)
6th	3.4 (4.7)	6.8 (2.0)	46.3 (6.5)	17.9 (4.9)	25.6 (4.4)
7th	3.3 (2.1)	7.9 (1.3)	46.1 (4.3)	19.0 (4.4)	23.7 (4.1)
8th	6.0 (7.8)	6.7 (2.3)	41.7 (6.1)	20.2 (6.1)	25.4 (4.5)
Decompression night	4.7 (5.0)	7.4 (3.0)	40.5 (6.0)	19.1 (4.1)	28.3 (2.3)
Postdive night					
1st	3.8 (5.7)	6.8 (1.8)	42.2 (3.5)	21.5 (6.2)	25.7 (4.5)
2nd	3.0 (6.2)	6.3 (2.4)	43.2 (5.1)	21.3 (3.5)	26.2 (4.6)
3rd	3.6 (5.9)	5.8 (1.8)	41.9 (8.0)	20.7 (5.2)	28.0 (3.7)
4th	2.2 (1.8)	6.5 (2.2)	45.0 (2.8)	18.8 (4.6)	27.5 (3.2)
ANOVA F ratio	1.65	1.55	1.30	0.87	1.19
P	NS	NS	NS	NS	NS

experiment.[1] However, the present study showed that, from the latter part of the bottom period to the postdive period, TST were slightly shortened in accordance with the lengthening of sleep latency, and SEI decreased as well. These results are different from those of Naitoh *et al*.[1] Whether these differences depend on the difference in dive depth or the difference in number of subjects is not known. Sleep latency is one of the best indexes for representing states of psychological tension and excitement.[4] From this fact, we can assume that the lengthening of sleep latency from the latter part of the bottom period to the postdive period was relative to the decompression and the psychological stress of long-term restriction in a closed environment.

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