Sleep–wake Regulation

Changes in sleep patterns during He-O_2 saturation dives

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Abstract During simulated hyperbaric saturation diving experiments of He-O_2 mixture at the depths of 150, 180 and 230 m the standard polysomnography of four divers, as well as their subjective feelings of fatigue, were recorded for 268 nights. In all three diving conditions, during the bottom period and the decompression period, wakes after sleep onset and Stage 1 sleep increased while Stage 4 sleep decreased. In deeper diving conditions stage 4 sleep tended to decrease and subjective feelings of fatigue increased. When the results are considered it can be assumed that the deeper the diving depths, the increased sleep disturbances and fatigue. However, it is believed that a fundamental sleep pattern will be maintained.

Key words fatigue, hyperbaric environment, saturation diving, sleep polysomnogram.

INTRODUCTION

Since the development of saturation diving technology,[1] it has become possible to dive deeper than 5–6 absolute atmospheres (ATA) by altering compressed air into He-O_2 or He-O_2-N_2 mixed gas. However, at depths of more than 16 ATA, high pressure nervous syndrome (HPNS) is observed.[2] In addition, it is indicated that the decrease of operational performance ability, lapses of consciousness, and sleep deprivation manifest at depths of more than 16 ATA. However, there have been few studies in this area of sleep polysomnography. In this study we examine the influences of simulated saturation diving on sleep at depths of 150, 180, and 230 m, as well as the differences of sleep patterns related to the diving depths.[3–6]

METHOD

Four healthy male divers were selected for all three diving conditions. Their mean age (standard deviation) was 26.0 (6.27) years in the 150 m diving condition (16 ATA), 30.8 (10.75) years in the 180 m diving condition (19 ATA), and 26.3 (5.38) years in the 230 m diving condition (24 ATA). In all three diving conditions, we first monitored the atmospheric pressure of the environment for 4 days (96.5 h), then began initial compression of air to 9 m depth pressure at the rate of 1 m/min at 10.00 h on the fifth day. From 10.30 h on the fifth day, we resumed compression using He gas at the rate of 30 m/h in 150 and 180 m diving conditions, and 25 m/h in the 230 m diving condition. We reached the target pressures after 5 h 17 min, 6 h 12 min, and 8 h 52 min at 150, 180 and 230 m depth pressure, respectively. The period of bottom stay was 186 h 43 min in the 150 m diving condition, 185 h 08 min in the 180 m diving condition, and 179 h 08 min in the 230 m diving condition. Afterwards, on the basis of the US Navy Diving Manual,7 we began decompression, and arrived at the postdive period after 147 h 10 min in the 150 m diving condition, 171 h 50 min in the 180 m diving condition, and 207 h 57 min in the 230 m diving condition; observing the postdive period for 4 days. In all three diving conditions night sleep was continuously recorded between 23.00 and 07.00 h, during the total experiment period, using standard polysomnography. Furthermore, during the experiment period we had the subjects record fatigue complaints before and after their sleep (prepared by the Industrial Fatigue Research Committee of the Japan Association of Industrial Health).

RESULT AND DISCUSSION

The results are shown in Table 1. In all three diving conditions, night sleep during the bottom period and decompression period showed a reduction in sleep period time and total sleep time, a decrease in the sleep efficiency index, and an increase of the number of the wakes after sleep and the number of sleep stage shifts. There was an increase in wakes after sleep onset and stage 1 sleep, and a decrease in slow wave sleep and stage 2 sleep. The changes of these sleep parameters revealed the same patterns in these three diving conditions. During the bottom period and the decompression period in the three dives, no change to REM sleep quantity was observed. However, in deeper diving conditions, slow wave sleep in the bottom period and in the decompression period decreased. Even on the night sleep returning to the absolute atmospheric pressure (postdive), there were a number of wakes after sleep and stage 1 sleep. This, together with the lengthening of sleep latency, maintained high level scores of feelings of fatigue. From the

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Table 1. Sleep variables during the saturation dives at the depths of 150, 180, and 230 m

	SPT (min)	TST (min)	SEI (%)	No. wake (*n*)	No. Shift (*n*)
150 m					
Predive	463.0 (6.3)	453.7 (6.2)	94.5 (0.9)	1.8 (0.4)	95.3 (15.1)
Bottom	452.3 (22.0)	430.8 (29.7)	89.8 (6.2)	5.7 (1.2)	101.8 (13.2)
Decompression	450.0 (10.6)	428.1 (13.8)	89.2 (2.7)	4.8 (1.5)	118.5 (12.4)
Postdive	460.0 (4.4)	442.5 (6.4)	92.2 (0.6)	3.0 (0.4)	99.3 (3.2)
180 m					
Predive	464.6 (12.7)	447.7 (14.3)	93.3 (0.9)	1.5 (0.7)	73.6 (23.3)
Bottom	457.5 (13.7)	432.1 (22.8)	90.0 (4.4)	5.7 (1.3)	102.9 (7.5)
Decompression	453.8 (8.9)	431.3 (9.1)	89.4 (2.1)	6.5 (0.8)	107.2 (8.8)
Postdive	424.2 (6.8)	401.0 (21.0)	83.5 (1.1)	2.3 (0.4)	88.6 (12.8)
230 m					
Predive	466.7 (4.5)	449.5 (6.7)	93.6 (1.3)	0.8 (0.4)	84.6 (5.1)
Bottom	458.8 (18.5)	428.6 (21.3)	89.3 (3.5)	5.3 (1.7)	97.3 (6.7)
Decompression	452.5 (7.6)	426.5 (8.7)	88.9 (1.9)	8.7 (2.0)	120.4 (4.9)
Postdive	445.4 (7.1)	423.1 (7.4)	88.1 (2.9)	1.9 (0.2)	84.5 (6.4)
Two-way ANOVA					
Phase (F value, *P*)	7.9, 0.001	6.5, 0.001	9.3, 0.001	19.8, 0.001	22.8, 0.001
Depth (F value, *P*)	2.2, NS	2.2, NS	2.1, NS	0.7, NS	5.5, 0.01
Interaction (F, *P*)	1.7, NS	1.8, NS	2.6, 0.05	2.9, 0.01	2.5, 0.05

Values are mean ± SD. ANOVA, analysis of variance.

above results, we assume that at deeper diving depths there are more sleep disturbances and an increase in feelings of fatigue, but that the fundamental sleep pattern is maintained.

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Sleep–wake Regulation

How does the distention of urinary bladder cause arousal?

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Abstract Under urethane anesthesia, the urinary bladder of male rats was distended by 0.3–0.5 mL of saline. When the animals displayed large amplitude delta waves, the distention caused tonic excitation in 76% (19/25) of the noradrenergic neurons in the locus coeruleus and in 53% (16/30) of the cholinergic neurons in the laterodorsal