INFLUENCE OF THE CHANGES OF CEREBRAL HEMODYNAMICS AND VIGILANCE LEVEL ON PSYCHOPHYSIOLOGICAL FUNCTION DURING SIMULATED MICROGRAVITY

Yuichi Inoue1, Shuichiro Shirakawa2, Kazuo Mishima3, kou Mizuno4, Hideki Tanaka2, Masamichi Sudoh5, hidetomo Saito3, Yoko Komada2,

1 Department of Psychiatry, Juntendo University School of medicine
2 National Institute of Mental Health, National Center of Neurology and Psychiatry
3 Division of Psychiatry, Akita University School of Medicine
4 Medical Research and Operation Office, National Space Development Agency of Japan
5 Division of Aerospace medicine, Jikei University School of Medicine

Summary of Research
Many researchers have investigated the characteristics of psychophysiological function under the condition with microgravity. However, relationship between the psychophysiological function and characteristics of both sleep structure and cerebral haemodynamics in space has not been well elucidated. If sleep deprivation occurs during the microgravity, findings of psychophysiological tests might show a deterioration depending on the fluctuation of vigilance level through circadian time course. In this study, we performed a series of investigation mainly focusing on the relationship between diurnal fluctuation of both vigilance level and psychophysiological function and nocturnal sleep structure. In addition, we evaluated the characteristics of hypopituitary adrenal axis (HPA) function which strongly correlates with the psychological stress level, and the effect of cardio-autonomic function manifested as the power spectrum of ECG R-R interval variations on HPA function.

Six degree head down tilt (HDT) was employed as a simulated condition of microgravity, and horizontal bed rest was adopted as a control condition. After two days of adaptation to the experimental environment, seven healthy young male subjects were set to HDT and horizontal bed rest for three days with cross over counter balanced design. Body impedance which evaluates the body fluid distribution, deep dermal temperature and power spectrum of ECG R-R interval fluctuations estimating cardiac autonomic function were simultaneously recorded for entire bed rest period. Overnight polysomnographic recordings were performed to investigate the characteristics of sleep structure on the first night of two bed rest conditions. In order to investigate the influence of HDT on diurnal variation of psychophysiological function and vigilance level, serial test sessions including the measurement of Stanford sleepiness scale (SSS) and absolute power of EEG power spectrum, event related potentials (P300), psychophysiological performance tasks indicating cognitive function and attention level were measured. Furthermore, computerized aptitude test (CAT) which comprised of dual task for evaluating both cognitive and tracking function were performed at the last of each session. On the third day of each bed rest condition, dexamethazone-CRH stimulation test (DEX-CRH test) was performed to evaluate the HPA axis dependent stress reactivity.

The impedance in the leg and water storage speculated from water intake and urine
volume were higher during HDT than horizontal bed rest in our subjects, indicating the increase in cerebral fluid in that condition. Although circadian body temperature rhythm did not differ between the two bed rest conditions, frequencies of nocturnal awakenings were significantly more frequent and percentages of stage 3+4 were significantly smaller during HDT. Regarding ECG R-R interval power spectrum, vagal tone manifested as both absolute value of high frequency component (HF) and ratio of low frequency component / high frequency component (LF/HF) was higher while nocturnal sleep and early morning hours during HDT. As for the results of the tests evaluating alertness level, absolute power of alpha wave was remarkably lower at 10 AM despite no difference in the values of SSS. Latencies and amplitude of P300 as well as the results of performance tasks for evaluating cognitive function and attention level did not differ between the two bed rest conditions at every test sessions. On contrary to those, tracking function manifested on CAT was significantly poorer at 10 AM session during HDT. With respect to the results of DEX-CRH test, statistical difference in the serum level of neither ACTH nor cortisol after stimulation was observed between the two conditions. However, it was noteworthy that cumulative values of HF and LF/HF through three days of bed rest periods were significantly correlated with the serum value of both ACTH and cortisol after stimulation.

From the above results, it was speculated that circadian rhythm could not be altered during short period of simulated microgravity, while minor sleep deprivation could be brought about by HDT. Although cognitive function could not be altered during HDT, dual task performance including tracking function was thought to be deteriolated in the morning hours of HDT. We speculate that this phenomenon might come from prolongation of sleep inertia brought about by relative predominance of parasympathetic function in the morning hours. Most striking finding in our results was that stress reactivity evaluated with DEX-CRH test was correlated with parasympathetic function, suggesting that CRH receptor might be supersensitized depending on the suppression level of sympathetic function.