Sleep in Microgravity

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Abstract- The aim of this paper is to compare data from longitudinal study of psycho-physiological and psychological characteristics of cosmonauts' sleep during pre-starts periods, space flights and both immediately after space flights as well as within time delay.

Physiological parameters of sleep were registered with mini poly-physiograph "SON-K", originally designed and developed at Bulgarian Academy of Sciences and installed on board of MIR space station. Questionnaires were used to receive data about subjective evaluation of sleep parameters. The results revealed that in the state of highly motivated, general mobilization of the organism (space flights), the subjective evaluations of sleep are very close to the objective evaluations via combination physiological registrations, i.e. electroencephalography, electro cardiology, electromyography registrations as well as breeding frequency and eye, body and limb movements. Data revealed that after flight cosmonauts' evaluation of their sleep significantly differed from objective assessments.

A co-relation between sleep EEG data and subjectively reported sleep characteristics exists and are important indicator of the functional state of the organism and/or of the level of stress reaction. No doubt at sleep consciousness is abolished although mental activity continues at a given levels. There are lots of evidences in the literature about mental activity, logic and responsiveness that persist at the time of sleep and definitely may have a protective role.

I. Introduction

The hazards of long-duration space flight are real. In order humans to plan and realize long-duration exploration of space, we must first secure the cosmonauts health. This is the only way to enable safe and productive exploration of space.

The sleep is complex multifunctional phenomenon and is part of human mechanisms for adaptation to the environment. Studies of human sleep made it possible to specify and evaluate its role for maintaining the functions of the organism and for determination of the work capacities and adaptive ability. The changes in the structure and organization of sleep, especially the deficit of some of its stages, substantially effect human labour effectiveness. Sleep impact on the effectiveness of our activities is significant especially in extreme environment such as stress, microgravity, etc.

There are evidences that many aspects of microgravity influence life, work and sleep patterns of cosmonauts. Cosmonauts often sleep poorly on Space missions. Crewmembers have from time to time reported an average sleep periods of 1 to 2 hours shorter compared to the typical sleep periods on Earth. Some sleeping difficulties are expected as on mission cosmonauts have little privacy, noises or other interruptions may occur, quarters are confined, cosmonauts have to become shift workers to handle numerous tasks related to the space mission. One NASA survey shows that about 50 percent of crewmembers use sleeping medication at some point during missions (http://neurolab.jsc.nasa.gov/sleephys.htm). However, despite cosmonauts' reports of poor quality of sleep in microgravity, there had been very little detailed studies of sleep in microgravity [1, 2, 3].

One of the most important problems in prolonged and super prolonged space flights is the preservation of the health and maintenance of capacity for effective work of the cosmonauts [4]. The pillars of health care system have been: selection, prevention and assessment of risks that for each mission class have to be minimized by training and medical supplies [5]. In this context protection of cosmonauts sleep for a long time is very important.

As a limited number of physiological studies of sleep in space are done up to now, the aim of this paper is to compare the data from longitudinal study of psycho-physiological and psychological characteristics of cosmonauts sleep in microgravity during pre-starts periods, space flights and both immediately after space flights as well as within time delay.

II. Material and Methods

Cosmonauts' sleep was studied during short- and long-term space flights on board of MIR space station. Continuous measurement of brain electrical activity – electroencephalogram (EEG); muscle activity, body and limb movements – electro myogram (EMG); eye movements; respiration frequency (electro plethysmogram EPG); cardiac activity (electrocardiogram ECG) and skin conductivity were registered. From these registrations we can determine changes in respiratory processes, relative muscle contribution to ventilation, sympathetic and parasympathetic regulation of heart rate variability, and the coupling between respiration and heart rate plus eye movements, all as a function of sleep

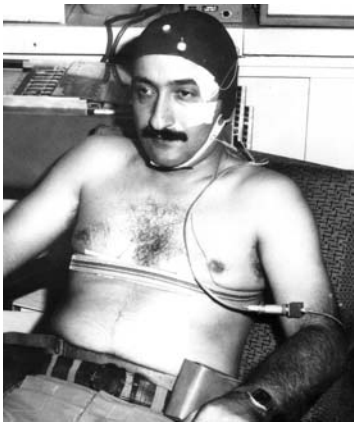


Fig. 1 Terrestrial testing of soft hat with embedded electrodes

stages. Combination of all these parameters is the bases of objective evaluation of duration and quality of various sleep stages.

For registration of EEG during sleep a soft hat with firmly embedded electrodes was used (Fig. 1). Pre-flight terrestrial test revealed that this hat was well accepted, very comfortable and did not cause problems or inconvenience to cosmonauts. Preliminary training of cosmonauts is a factor of a considerable importance for the registration of reliable and free of artefacts records. Cosmonauts' high motivation, strict obeying to terrestrial instructions and positive attitude towards physiological registrations have played a significant role and were of enormous help in collecting sleep records. When the cosmonaut manifested goodwill to follow all of the commands and are motivated to acquire precise investigations, the results are of high quality. Unfortunately some of the subjects examined and trained for space flight did not meet these requirements. Their records were rejected from further analyses.

Physiological parameters of sleep were registered with mini poly-physiograph "SON-K", originally designed and developed at Bulgarian Academy of Sciences and installed on board of MIR space station (Fig 2).

Once all polysomnographic measures are conducted, they were followed by a post sleep subject survey to determine subjective assessment of sleep quality. Subjects responded to questions designed to elicit their subjective opinions regarding the duration and quality of sleep. Cosmonauts had to evaluate time to go to sleep (4 steppes); duration of sleep; character of the sleep (superficial or deep); number of arousals and movements. The data gave possibility to compare the coincidence into the subjective estimation of sleep parameters and objective data in percentage. Thus through qualitative evaluation, utilizing polysomnographic registrations and subjective measures, assessment of sleep was achieved.

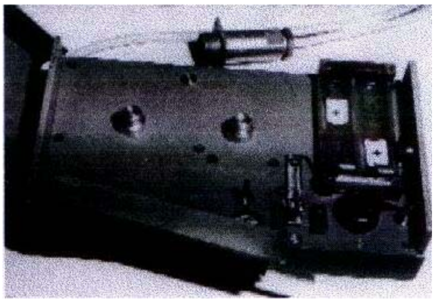


Fig. 2 Poly-physiograph device SON-K

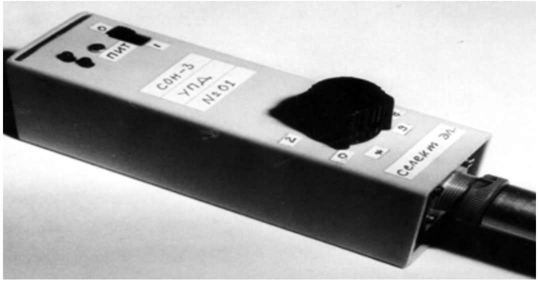


Fig. 3 Electrode correction and checking device

27 poly-physiological sleep registrations plus corresponding questionnaires were analyzed for this paper. They were reordered during pre-starts periods, at space flights and after space flights – immediately and within time delay up to 4 months. Based on poly-physiological records, sleep stages were visually detected. Reihtsthafen and Kales [6] worldwide accepted classification was used. Specific attention was paid to inter phase coefficients and index of the sleep at different stage as well as on sleep cyclicity.

III. RESULTS

The results revealed that:

First, it was straightforward proven that applying mini poly-physiograph recorder and always using a unique electrode correction and checking device (Fig. 3), precise, satisfactory, free of artefacts records may be obtained even under the extraordinary conditions onboard the space station.

Second, the results showed that sleep structure of cosmonauts preserved all typical stages of normal sleep (Fig. 4).

Third, however the contents and organization of sleep stages of cosmonauts differed from the norms (Table 1). Pre-flight periods are characterized with very slight decrease of deep sleep (stages III and IV) and dramatic reduction of REM sleep. There were even records of one of the cosmonauts in which REM was entirely missing. In the space, the situation is a little bit different. The paradox is that although deep sleep, stages III and IV, were satisfactory expressed (37.18

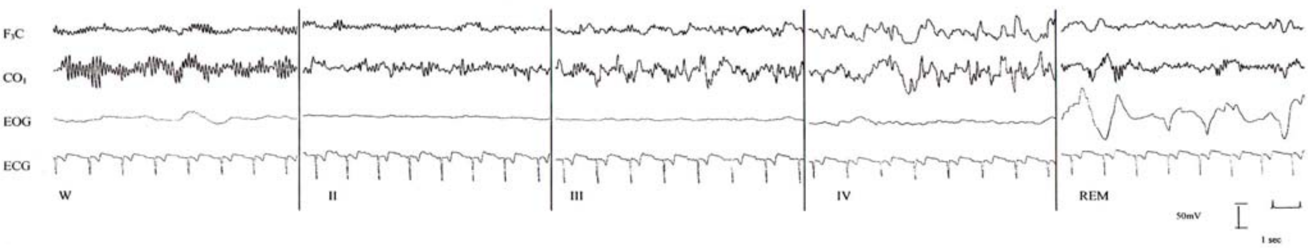


Fig. 4 EEG of sleeping cosmonaut - all stages of sleep are preserved

min average duration) and even increasing reaching to 66.48% in one of the cases, the last stage, REM was definitely decreased. At the same time first 2 stages or the superficial sleep has been decrease especially in log-term missions exceeding 3 months in the space. Fig. 5 illustrates records of various sleep stages during a short-term flight. Results obtained via sleep registration during 3 nights are presented in percentages. They are based only on poly-physiological measures and are absolutely objective.

Table 1. The sleep stages expressed as percentage during long-term space flight

Period	Superficial (stages I+II)	Deep (stages III+IV)	REM
Normal sleep			
	45-55	Up to 35	20-25
Pre-flight period			
	46.03	29.62	3.17
In space			
1 month	37.00	46.60	11.00
3 months	38.20	25.18	18.84
5 months	19.91	52.51	22.54
7 months	23.50	58.27	14.66
8 months	15.73	49.05	15.02
Average	26.87	46.32	16.41

In addition to above mentioned data, it is essential to underline that the time for falling asleep was most frequently shortened. The latent period of the common sleep was short - from 5 to 8 minutes during the preparation period and from 2 to 10 minutes during short-term space flight. The latent periods of the III-rd and IV-th sleep stages were also reduced. During short-term flights deep sleep usually aroused after the first 10 minutes had passed. On the contrary the latent periods for falling asleep and for the appearance of deep sleep stages were considerably prolonged during long-term (several months) flights. It reached 1hour and 20minutes for the slow wave sleep in the record made in the 7th month of the flight (Fig. 6).

Fig. 7 summarizes a comparison of qualitative polysomnographic sleep registrations and subjective evaluations. During space flight and other periods of increased strain as the preparation period and immediately after landing, the subjective evaluation of the sleep parameters and the objectively registered results concerning the duration, depth and number of awakenings have coincided. Out of these periods the results revealed a marked discrepancy between the subjective and objective evaluation of sleep. As already mentioned, in the questionnaires presented to cosmonauts, they made subjective evaluation of their own sleep during all the time. They made extremely accurate characteristics in these self-reports especially in the state of highly motivated, general mobilisation of the organism as is the space flight period. The coincidence varied from 78% up to 89%. Thus, the subjective evaluation

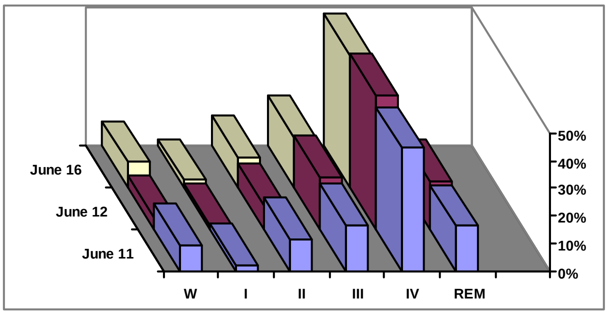


Fig. 5 Sleep stages at 3 flight days

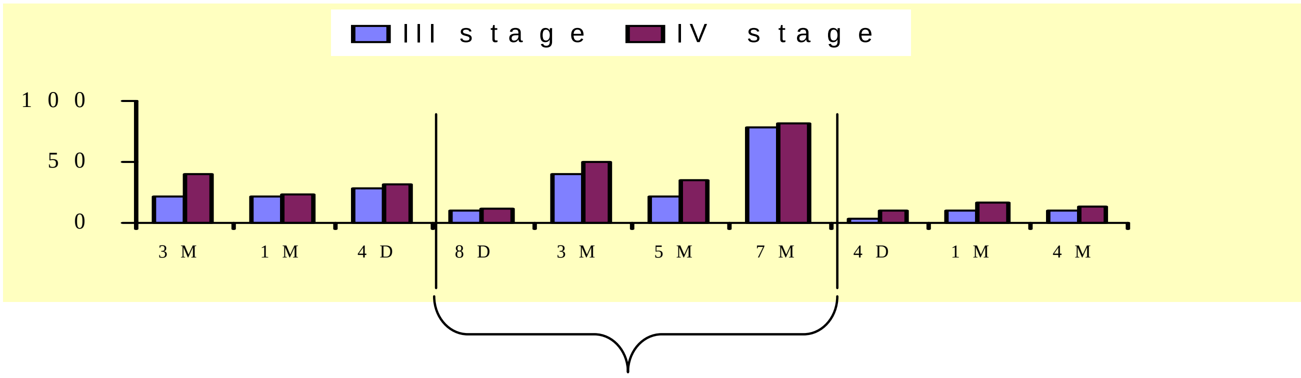
of cosmonauts sleep is very close to the objective evaluation via combination physiological registrations. It is the periods during space flights and immediately pre-stare and after space flights period that are characterized with such precise estimations. In the period within time delay evaluation that cosmonauts make on their own sleep significantly differs from the objective data.

IV. Discussion

The conditions of microgravity are one of the very aggressive extreme conditions [7] in which the man have to exist, work and fulfil complex activities. Space flights secure possibilities for arising of all sleep stages and components that are observed on earth. Despite of this fact, their distribution and organisation are significantly changed [3]. The sleep database under microgravity conditions remains poor [8]. Nevertheless the results obtained till now suggest that in microgravity cosmonauts can sleep well. This fact is very important as sleep deprivation is a very strong stress provoking factor [9].

The discrepancy between the subjective and objective evaluation of sleep long before space flights as well as long after the end of space missions from one hand, and their coincidence in the periods of increased strain, i.e. space flights, on the other, demonstrated cosmonauts potential for more realistic evaluation of the sleep parameters in time of high motivation and responsibilities. This is probably demonstration of preservation of mental activity during sleep and definitely has a protective function. The interweaving of conscious process and sleep is not an accident but it is conditioned by situational need that involves one protective mechanism or another. Really, the mechanisms of consciousness and mental activity during sleep are mechanisms that cannot be investigated experimentally, directly, at the level of the subject's feelings. The only possible way to study such phenomena is to compare (a) the objective physiological registrations recorded simultaneously to subjective experience with (b) the report of subject on this specific phenomena and his/her personal judgment about it [10].

Therefore, the studies in this field may offer a method of investigating both the stress-reaction and the nature of mental activity during sleep.



Pre-flight period Flight After the flight

Fig. 6 Latent periods of III-rd and IV th sleep stages before flight, in flight and after flight observed during different flights. On axis X months (M) and days (D) are indicated

The long duration of deep sleep was probably connected with unusual psychic strain and exhaustive spending of energy during the flight. It is well known that the slow-wave sleep is connected with an intensified energy synthesis. The overwork in wake time has decreased the latent period of the slow wave sleep. This result confirms the vitally essential function of the deep sleep for the organism and the increased need of its production after a period of overloading. The increase of the slow wave sleep duration is a response aimed at a fuller mobilization of the restorative reactions of the organism. This ability of the organism is has been obviously reduced during long-term flights, the latent period is significantly increased and slow wave sleep decrease which are an indication of exhaustion of the adaptive mechanisms.

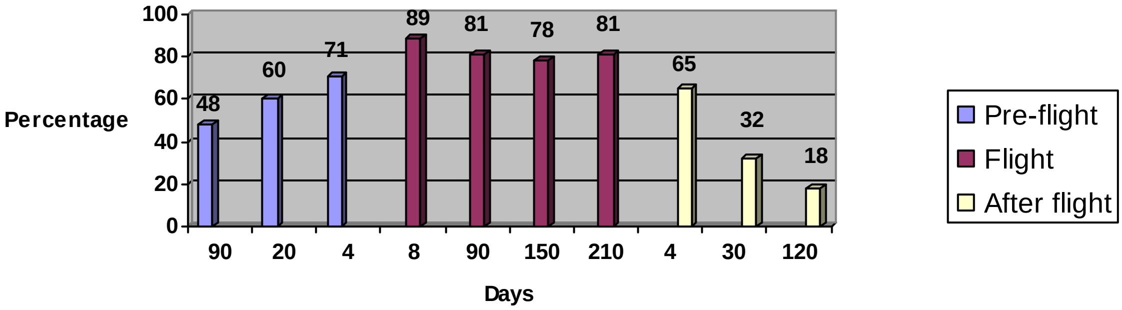


Fig. 7 Summary of comparison of qualitative polysomnographic sleep registrations and subjective evaluations

The strategy for protecting cosmonauts’ health and performance during long-term space flights dictates the necessity of systematic monitoring of entire sleep process at all stages of preparation, implementation and return from space flight.

Sleep is an individual characteristic that is highly influenced by the unique characteristics of each organism. Revealing the characteristic “good-sleeper” is of enormous significance for the process of selection of cosmonauts and for the success of each space mission. To be a "good sleeper" under the uncomfortable space conditions seems to be to a high degree a question of individual abilities. They would possibly be included into the bio-portrait of the ideal astronaut.

As the results revealed, the applied psycho physiological assessment of cosmonauts’ sleep during MIR space mission is not only feasible, but yields reliable data that can be related to mission demands in a meaningful way. The unique methodology that has been for the first time employed in late 70’s of last century may be of great promise for the development of techniques that provide daily monitoring of physiological cost of mission demands. The same approach can also be used for better understanding of problems that can arise with regard to the functioning of individual crew members. The results of these studies are not limited only to the space programs. We can also use the information of the effects and mechanisms of the physiological changes engendered in space and the applied preventive and rehabilitative methods developed to combat these changes to the benefit of those on Earth who are facing similar physiological and psychological difficulties such as civil aviation pilots, patient with sleep disorders, etc.

REFERENCES

[1] J. C. McPhee, and R. J. White, "Physiology, medicine, long-duration space flight and the NSBRI," *Acta Astronaut.* Vol. 53(4-10), pp. 239-248, August -November 2003

[2] C. J. Wientjes, J. A. Veltman, and A. W. Gaillard. "Cardiovascular and respiratory responses during a complex decision-making task under prolonged isolation," *Adv Space Biol Med*, vol. 5, pp. 133-155, 1996

[3] I. M. Stoilova, T. K. Zdravev and T. K. Yanev, "How human sleep in space--investigations during space flights," *Adv Space Res*, vol. 31 (6), pp. 1611-1615, 2003

[4] I. M. Stoilova, I. I. Ponomareva, I. Miasnikov, Hr. Ivancheva, V. Polyakov, O. Zhukova, and N. Peneva, "Study of sleep during a prolonged space flight of the "MIR" orbiting station"in *Current trends in cosmic biology and medicine*, K. Boda, Ed., Slovac Academy of Scieences, 1990, pp. 85-90

[5] J. D. Collier, "Health care in extreme Environments," in *12-th Man in space symposium "The Future of Human in Space*", W.,D.C, p.23., 1997

[6] R. Reihtsthafen, and K. Kales, *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects*, Bethesda, U.S. Government Printing Office, 1968, p.204

[7] O. G. Gasenko, From Ocean Depth to Deep Space, Publisher APN, Moscow, Russia, 1986 (in Russian)

[8] O. Quadens, Ph. Degual, R. Olieslagers, and K. DeMetz, "*Space Scientific research in Belgium*", Fed. Office for Sci. Technic. and Cult. Affairs, Brusselles., vol. 1., 1997, pp 59-68

[9] A. Wein, and K. Hecht, "Sleep electropoligraphical and other electrophysiological methods for investigation of nocturnal sleep, in Human sleep," in *Physiology and Pathology*, Meditcina, Moscow,, Russia, 1989, pp. 76-85, (in Russian).

[10] L. M. Puchinskaya, "Consciousness and Brain," II-nd Internat. Sympos. Moscow, 1994, p.44