SLEEP EFFICIENCY UNDER EXTREME FACTORS INFLUENCE

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Key words: *Sleep; efficiency coefficient; space flight*

Abstract: *Human sleep structure and variations of its different parameters are in a definite relation with the intensity and character of different endogenous and exogenous factors. Investigation of sleep efficiency gives the possibility to calculate which part of the time in sleep was usefully used for rest and relaxation and also for recovering and restoration processes in the organism. Investigation of these changes gives the possibility to determine the reason for deviations established in organization and structure of sleep. We performed in our studies of sleep investigations of sleep efficiency during space flights as well as of different coefficients of the sleep structure. The results obtained revealed that latent times of the different sleep stages were changed in space flight. REM phase was significantly changed in quantity and structure during space flight and these changes influenced on the sleep coefficients calculated and sleep efficiency. Nevertheless sleep efficiency is comparatively well preserved under space flight but only during short space flight. The stay duration and individual astronauts' features can have influence on the sleep efficiency preserving. The investigations performed revealed that human can keep sleep efficiency what is too important under extreme conditions.*

Sleep efficiency in space flight (SF)

Sleep efficiency is an indicator for that which part of the time appointed and spent in sleep was used not only for rest and relaxation but also for recovering the energy balance, for balancing the processes of excitement and retention, for balancing hormones production in human organism (Drucker-Colin et al., 1982]. Sleep efficiency coefficient (SEC) depends on total sleep duration, duration of deep sleep (DS), time needed for falling asleep (latent period) and time spent in awaken state and in superficial sleep (SS). Human sleep structure and variations of its different parameters are in a definite relation with the intensity and character of different endogenous and exogenous stress effects [Sinton C., 1983]. Investigation of these changes gives the possibility degree of sleep usefulness to be calculated and on the other hand degree of the affect of stress factor, the reason for deviations established, to be determined. In some cases at space flight (SF) SEC reaches significantly large values (for astronaut A.A.). It is an indicator for good adaptive reaction and preserved ability for recovering under extreme conditions.

Material and methods

We elaborated special multi-channel registering device (poly-physiograph) with a miniature size for its time for sleep registering and analysis in space conditions (Дунев, 1985). It was supplied from small batteries and its construction was consistent with the requirements for space appliances. That device could register for 8 hours 6 physiological parameters needed for sleep analysis. Physiological and electrophysiological parameters were registered, which were necessary for the complete sleep characterization and valuation as well as for calculating SEC under SF conditions. Electric brain activity (EEG), eyes movements (EOG), electromiogram (EMG), electrocardiogram (ECG) and respiration frequency were registered.

Analysis were performed in our investigations of sleep efficiency as well as of different coefficients of the sleep structure revealing the relation between different sleep stages – superficial sleep (SS), deep sleep (DS) and paradoxical (rapid eye movements (REM) sleep), respectively K_1 – SS/DS; K_2 – SS/REM; K_3 – DS/REM. SEC was calculated according to the formula suggested by Vein and Heht (Вейн и Хехт, 1989].

$$SEC = \frac{TotalSleepDuration(\min) + DS(\min)}{LatentTime + AwakenState(\min)}$$

Parameters needed for SEC calculation during different stages were measured – latent time values for the total sleep (the time from lie down till the first sleep EEG symptoms); latency of DS and REM sleep (respectively the time from lie down till the first slow waves occurrence in EEG registrations or till the first REM-sleep parameters occurrence).

Results

It was established that latent times of the different sleep stages were changed. In some cases at prolonged stay in SF latent period of the total sleep and especially of deep sleep was significantly longer while in other cases latency of the total sleep and its different stages could be significantly shortened in comparison with the normal values (Fig.1). The average value of the sleep latency at pre-flight period was about 8 minutes and for III and IV stages about 19 minutes, which means that after 7th minute the astronaut fell asleep already and after 19th he already slept in deep sleep. As it is seen in the figure at 9th flight day 10 minutes after eyes closing slow waves sleep appeared.

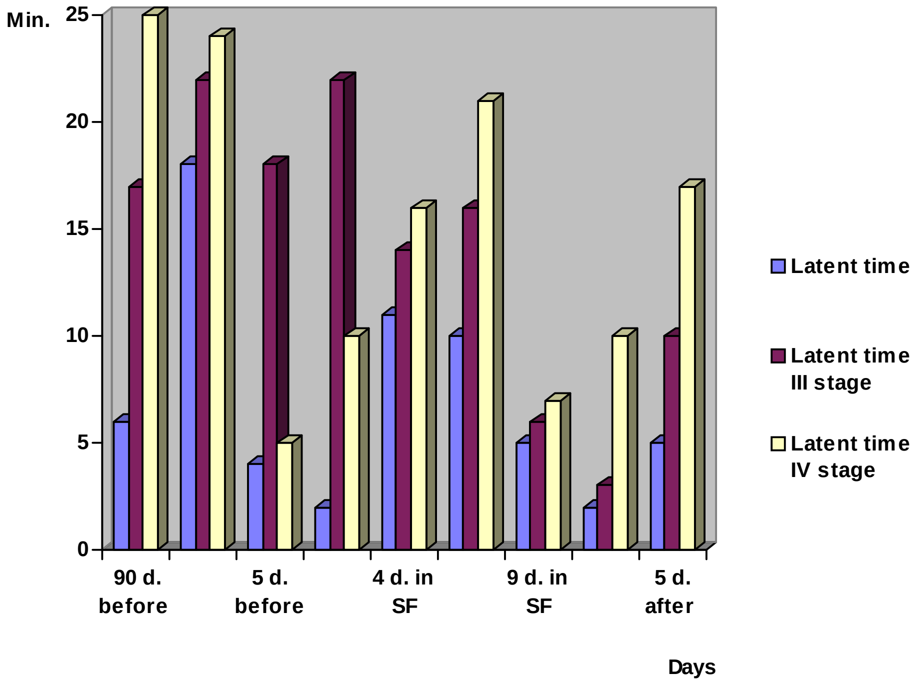

Fig. 1. *Exemplary diagram of latent time of the total sleep and III and IV sleep stages of the cosmonaut A.A.*

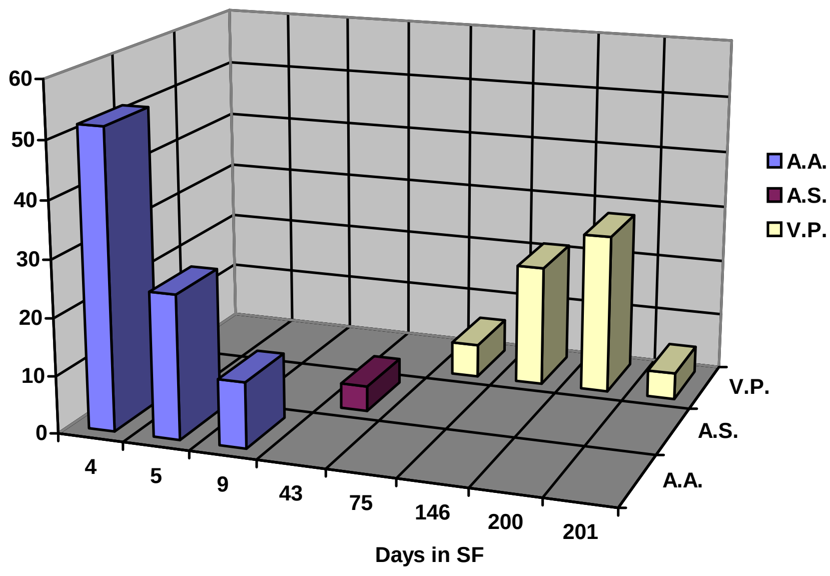

Fig. 2. *SEC during space flight for cosmonauts A.A., A.S. and V.P.*

__Table 1.__ The different sleep stages from the different flight phases for 4 cosmonauts

Cosmo-naut	Reg. time	Alert ness	Lat. time	REM	SS (I+II)	DS (III+IV)	К$_1$ П/Д	К$_2$ П/R	К$_3$ Д/R	SEC
A.A.	90 d. before	13.9	6	26.2	234.89	338.42	0.69	10.32	12.91	46.05
A.A.	32 d. before	69.4	18	22.75	249	186.66	1.33	10.94	8.20	7.97
A.A.	5 d. before	3.08	4	40.05	157.18	249.62	0.63	3.92	6.23	98.81
A.A.	4 d. before	9.4	2	23.56	117.84	344.13	0.342	5	14.6	73.60
K.S.	5 d. before	3.24	20	47.23	97.71	27.28	0.358	2.068	5.776	29.85
K.S.	4 d. before	1.85	7	23.11	195.49	245.02	0.797	8.46	10.60	80.23
V.S.	before flight	28.8	18	31.8	183.3	56.1	3.26	5.76	1.76	7.60
V.P.	before flight	40	9	6	87	56	1.55	14.5	9.33	5
A.A.	4 d. in SF	6.56	11	72.2	122.48	356.67	0.343	1.696	4.94	52.08
A.A.	5 d. in SF	22	10	85	49	323	0.152	0.58	3.8	25.06
A.A.	9 d. in SF	48.54	5	0	69.93	246.33	0.283	-------	---------	11.41
A.S.	43 d. in SF	89.46	30	9.24	215.04	106.26	2.024	23.27	11.5	4.40
V.P.	4 d. in SF	23	3	48	162	204	0.79	3.37	4.25	24.65
V.P.	75 d. in SF	67	17	71	144	95	1.51	2.028	1.34	5.82
V.P.	146 d. in SF	23	10	103	91	240	0.38	0.88	2.33	21.66
V.P.	200 d. in SF	19	11	78	125	310	0.40	1.60	3.97	28.06
V.P.	201 d. in SF	86	40	64	67	209	0.32	1.046	3.26	4.67
A.A.	1 d. after	12	2	15.42	68.29	204.24	0.334	4.43	13.24	40.81

REM phase was significantly changed in quantity and structure. It diminished up to total disappearance in some cases. It affected SEC values and especially the values of the coefficients K_2 and K_3. It was registered at initial registrations lengthening of deep sleep but slow sleep decreased at the end of the flight and during the flights with several month duration. These changes influenced on the sleep coefficients calculated and sleep efficiency. Sleep efficiency is comparatively well preserved under space flight sojourn (Fig. 2).

However the stay duration and individual astronauts' features can have influence on the sleep efficiency preserving. Fig. 2 represents graphical values of SEC for cosmonaut A.A. for 3rd, 4th and 8th SF day; for A.S. for 43rd SF day and for V.P. for 1st, 3rd, 5th and 7th SF month. It can be seen in the figure that sleep efficiency was better preserved during short stay in SF and gradually decreased with the increase of the flight duration and it is less than 5 at the end of the 8th month of the V.P.'s flight (Table 1). The table shows the values of all coefficients and SEC for different cosmonauts and flights with different duration. The quantity of different stages is also shown – alertness, superficial sleep, deep sleep, REM for different flights.

Discussion and Conclusions

The investigations performed revealed that human can sleep enough even under quite unusual and tough extreme conditions as microgravity as well as to keep sleep efficiency. It is too important under human exhausting conditions. Depleting extreme influences often lead to significant shortening of sleep latent period. Significant parameters from so called inside sleep structure (sleep organization) were changed and it might affect on the following adaptive processes course, recovering, balance in the cyclic recurrence in human organism and disturbance of chrono-biological rhythm [Drucker-Colin, 1981; Drucker-Colin and Valverde, 1982].

The short latent period of the total sleep in part of the cases is indicative of the increased necessity of sleep under exhausting extreme conditions. Preserved SEC in most of the cases shows the increased necessity of deep sleep production namely at which organism energy-recovering processes are performed. It is known that the more exhausting conditions of the respective extreme environment are the more energy spending is larger and the necessity of recovering is higher. It reflects in the lengthening and fast occurrence of deep sleep. The possibility for deep sleep production is an evidence for spare mechanisms use turned on during constructive phase of the stress endured. However the lengthening of the latent period for the deep sleep (up to 120 minutes and more in some cases) especially at the end of the stay under extreme environment is a proof of exhausting the adaptive brain mechanisms responsible for that important sleep phase production.

REM-sleep is the time at which events experienced are balanced and accumulated redundant information is reduced. Exactly REM is related to regulation of the relationships excitement/retention processes [Stock, 1982]. REM-sleep not only appeared slowly and with difficulty in the total sleep time but it was also significantly decreased in quantity under extreme conditions applied by us. It is one of the serious indicators for occurrence of disadaptation changes in organism.

The study of sleep efficiency is an important auxiliary method which can be used for prove of the sufficient sleep completion under extreme conditions and its use is undeservedly neglected. Preservation of high efficiency and normal ratio between different sleep stages is a security for better general condition and higher degree of work capacity [Поляков, 1994]. It is possible in that way by means of different sleep coefficients fast and accurate appraisal of the general state to be made and to forecast future dangerous and undesirable physiological deviations.

Preserved production of deep sleep in SF is most probable to be related to the needed increased energy synthesis because the work of the astronaut is related to expending of large quantity energy reserves [West, 1997].

SEC kept values larger than 10 for almost all of the investigations which is an indicator for the lack of neurotic deviations (Stock, 1982).

The lengthening of latent times of different stages as well as the changes in sleep coefficients and decreased sleep efficiency are related to lower work capacity of astronauts. They are also indicative for the beginning of disadaptation changes, make worse the general condition and influence on the velocity and quality of psycho-physiological tests and tasks performed. That is why the shortened latent periods of the different sleep stages as well as optimum values of sleep coefficients and SEC for A.A. are regarded as especially favorable and they are indicator for stable and highly adaptive physiological facts for him. The appearance of unexplained weariness is an important sign for sleep inferiority. It feels quite tangibly under microgravity conditions. The weariness unifies a set of factors appeared as a consequence of decreased living capacity (Connor, 1985). The relationship between the lost of sleep or its inferiority and appearance of weariness is categorically proved. That fact is especially actual when means for sleep improvement are looked for. Medicaments use for improving the sleep at space flights is not exception and it has been applied in a lot of cases. However the possibility that soporific can affect the attention, concentration, reaction time, which is emphatically undesirable under these conditions, should be considered.

REM-phase of the sleep is related to information processes and memory functions of the brain (Stock, 1982). Repression of that sleep stage can lead to neurotic manifestation development and increase of the psychic strain during alertness time. The opposite is also valid – if there was emotional stress during daily engagements (parachute jumping, exams) then significant decrease of REM sleep in EEG registrations was established (Dincheva and Tsaneva, 1982).

Namely because of these reasons sleep preserving under space conditions is especially important for the prolonged flights. Appearance of disadaptation and exhaustion found in sleep parameters including SEC values limit the comfort of the prolonged sojourn. That is why the efforts directed toward keeping normal in organization and structure sleep in SF are justifiable.

Acknowledgment

This study was supported by National Science Fund of Bulgaria under contract NIP L-1530/05.

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