

INVESTIGATIONS OF HUMAN MOTOR FUNCTIONS UNDER THE CONDITIONS OF AN ALTERED DAILY REGIMEN

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ABSTRACT: Investigations of the effects of an altered daily regimen upon muscular strength and endurance are reported.

The question of the resistance of human motor functions to specific conditions acquires great significance in connection with the problem of extended space flights. A number of authors (Yu.V. Vanyushina et al., 1966; L.I. Kakurin et al., 1966, and others) showed the influence of unfavorable factors (hypodynamia, changed regimen of eating, etc.) on the neuromuscular apparatus. However, there remains the little-studied question of change in human motor functions during a prolonged stay in close quarters under the conditions of an altered daily rhythm. /159

We investigated the influence of an altered daily rhythm¹ (18- /160 hour daily rhythm) on the function of the muscular apparatus. We applied a number of methods for defining the precision and resistance of the indices of simple motor reactions and muscular activity. In the 15-day experiment three subjects took part (Subject M., Subject I., Subject S.).

Measuring muscular strength and static endurance was carried out with the aid of a manual dynamometer of special construction by B.M. Abalakov (Central Scientific-Investigatory Institute of Physical Culture). Measurements were taken before and after the experiment and also on the 4th, 7th, 10th and 13th day, before the first and second watch and also after the watch. Measurements of strength and endurance of basic muscle groups were taken before and after experiments on a special test stand, which permitted particular muscle groups to be investigated in flexor and extensor movements of the forearm, the shoulder, the trunk, the hips and the lower legs.

Investigation of the muscle-joint system and the coordination of movements in small and large exertions were made with the aid of a dynamometer. Under the experimental conditions, it was necessary for the right hand to repeat small (1/10 of maximum) and large (1/2 of maximum) predetermined efforts. The actions had to be performed without looking at the indicated dynamometer.

¹The experimental conditions are described in the article by A.A. Veslova, N.A. Gurovskiy et al. included in the collection of essays.

The habit of judging one's quantitative exertions was developed and intensified in preliminary experiments. On the same dynamometer, a study of the "sense of time" was carried out (on 3 and 10 seconds) which was developed before the experiment. There, the subject exerted a quantity (small or great) force with his right hand; with his left, he used a stop watch. During the development of small and large exertions, mistakes in reproduction of a given force for a given duration were evaluated.

In order to make a complete study of motor functions, a "stabilograph" developed in the Central Scientific Institute of Physical Culture was used to evaluate the ability to meter efforts precisely with redistributed pressure underfoot. The method is the following: /161 the subject stands on a stabilographic platform and takes a standard pose (usual standing). He must follow a "program" curve which had been plotted earlier on a moving paper tape of a recorder, and by redistributing the pressure on the rim of the stabilographic platform, control the pen of a recording galvanometer, producing maximum coincidence of his curve with that of the program.

For analysis the indices of disaccord were considered, expressed in arbitrary units, as well as the results of their statistical treatment. In order to evaluate the abilities and the alternation of activity of specific muscular groups, periods of voluntary tension and relaxation of the skeletal muscles (according to V.O. Fedorov) was used. The indices of latent times of tension (L.T.T.) and relaxation (L.T.R.), and also their relationship (L.T.T./L.T.R. index), was developed as a generally accepted method of mathematical statistics.

According to the data of the investigation of muscular strength and static endurance, muscle-joint sense and the duration of development of small and large isometric forces, sharp changes or weakening were not observed. However, it is possible to note essential fluctuations of muscular strength, muscular endurance of the hand, muscle-joint sense, "the sense of time" and the daily dynamics during the experiment. Especially large changes according to these indices were noted for subject M. At the end of the experiment his muscular strength dropped by 7 kg; results characterizing the muscle-joint sensitivity to a small effort worsened. For the same subject one must also note a significant fluctuation in the sense of time and the muscle-joint sense according to data obtained in the first and second watch and also each day of the experiment. Such changes in indices characterizing an adaptability on a subtle plane in the organism to /162 a definite regimen of life activity can be explained evidently by the fact that his daily periodicity was seriously disturbed, and the adaptation to a new change in sleep, waking and work had not yet taken place. For the two other subjects during the experiment there was noted a less pronounced shift in muscular strength and in data characterizing strength response and intervals of time. In comparison with the measurements taken before the experiment, during the 4th, 7th and 10th days, for subject I. there was a small increase in

muscular endurance. It was characterized by a stable amount of from 25-30 seconds during the 4th, 7th, 10th and 13th day of the experiment.

For subject S. a significant lowering of muscular endurance was observed, which after the experiment diminished for the right hand from 35 to 17 seconds, and for the left from 42 to 12 seconds. In addition, the muscular endurance already by the 4th day of the experiment dropped in comparison with the original data by 7 seconds for the right hand. The sharp lowering of muscular endurance evidently indicates the lesser degree of training of this subject to similar type of experiments, as it was only the second time he had taken part in experiments while the two other subjects, M. and I., had been participants in many extended experiments in the chamber. The muscular endurance for subject S. in the first watch during the entire experiment (4, 7, 10, 13th days) was more than after the watch, which indicates signs of developing fatigue toward the end of the watch. For subjects I. and S. the "sense of time" and the muscle-joint sensitivity indices for small and large forces improved the longer they stayed in the hermetically sealed chamber in comparison with the first phase, which indicates a certain adaptation of the organism to the alternation of various periods of sleep, work and rest. Materials received by the method of program stabilography indicated that subjects I., M. and S. underwent the complex restructuring of daily rhythm differently. The initial and final values of the indices of error in the stabilogram demonstrate a pronounced improvement and the completion of the tests for subject I. and M. and a lack of any noticeable change for S. (Table 16).

TABLE 16. RESULTS OF ANALYSIS OF STABILOGRAM FOR SUBJECTS BEFORE AND AFTER THE EXPERIMENT. /163

No. of Attempts and Statistical Characteristics	I.		S.		M.	
	Before	After	Before	After	Before	After
1	673,5	398,0	420,0	469,0	754,0	558,0
2	460,0	494,5	486,0	474,5	634,0	494,5
3	435,5	440,0	508,0	499,5	520,0	456,0
4	517,5	395,0	501,5	336,5	518,5	464,0
5	360,5	421,5	375,5	406,5	574,0	410,5
M $\pm$ m	489,5 $\pm$ 52,45	429,8 $\pm$ 18,14	458,1 $\pm$ 25,98	437,2 $\pm$ 29,47	600,1 $\pm$ 43,93	476,6 $\pm$ 24,39
$\sigma \pm m$	117,3 $\pm$ 37,09	40,56 $\pm$ 12,82	58,1 $\pm$ 18,37	65,9 $\pm$ 20,84	98,22 $\pm$ 31,06	54,54 $\pm$ 17,25
v, %	$\pm$ 24	$\pm$ 9	$\pm$ 13	$\pm$ 15	$\pm$ 16	$\pm$ 11
P, %	$\pm$ 11	$\pm$ 4	$\pm$ 6	$\pm$ 7	$\pm$ 7	$\pm$ 5
t		1,08	0,53			2,46

In Table 16 the differences in statistical characteristics are shown. Thus, for subject S. the criterion of reliability of differences is 0.53, for I. and M. 1.08 and 2.46, respectively. Moreover, indices of fluctuations of the sign show the difference in the

subject's reactions to the action of the factor: S., ± 15 and $\pm 7\%$ against ± 13 and $\pm 6\%$; subject I., ± 9 and $\pm 4\%$ against ± 24 and $\pm 11\%$; for M., ± 11 and $\pm 5\%$ against ± 16 and $\pm 7\%$, respectively (see Table 16). It is possible to assume (on the basis of control experiments) that for subject S., as opposed to I. and M., a natural scientific performance of tests was "blocked" by complex experimental conditions and a radical change in the daily rhythm of life activity.

On the basis of the total analytical data, it is possible to judge that stability of the maintenance of position was practically unchanged, and subject M. was even more resistant to the effect of this factor (according to the given tests). Results of electromyographic analysis of the ability for maximally quick alternation

TABLE 17. LATENT TIME OF TENSION AND RELAXATION FOR SUBJECT M. IN /164 THE SECOND EXPERIMENT.

Muscles	LTT _{max} millisec		LTR _{max} millisec		LTT _{max} LTR _{max}		LTT _{min} millisec		LTR _{min} millisec		LTT _{min} LTR _{min}	
	Be- fore	After	Be- fore	After	Be- fore	After	Be- fore	After	Be- fore	After	Be- fore	After
Sural												
right	420	380	440	210	0,955	1,810	240	100	130	130	1,263	0,769
left	420	420	380	300	1,105	1,400	280	240	210	60	1,333	4,000
Tibial												
right	340	360	410	360	0,829	1,000	220	180	390	200	0,564	0,900
left	500	340	480	420	1,042	0,810	210	180	350	200	0,553	0,900
Right Hip												
right	510	240	480	230	1,063	1,043	230	160	460	140	0,500	1,143
left	300	480	440	370	0,682	1,297	160	380	320	180	0,500	2,111
Biceps of												
the Hip												
right	480	490	560	240	0,857	2,042	180	220	300	220	0,600	1,000
left	380	520	440	510	0,864	1,020	260	120	220	220	1,182	0,545
Biceps of the												
Shoulder												
left	350	320	310	470	1,129	0,681	300	180	280	290	1,071	0,621

TABLE 18. RESULTS OF STATISTICAL DEVELOPMENT OF INDICES OF LATENT TIME FOR SUBJECT M. BEFORE AND AFTER EXPERIMENT (VOLUNTARY TENSION AND RELAXATION OF MUSCLES).

No. of Attempts	Index	M $\pm$ m		$\sigma \pm m$		v, %		P, %		
		Before	After	Before	After	Bef.	Aft.	Bef.	Aft.	
1	LTT _{max}	411 $\pm$ 25,1	394 $\pm$ 31,1	75,4 $\pm$ 17,8	93,4 $\pm$ 22,0	$\pm$ 18	$\pm$ 24	$\pm$ 6	$\pm$ 8	0,42
2	LTR _{min}	438 $\pm$ 22,7	346 $\pm$ 35,6	68,2 $\pm$ 16,1	106,7 $\pm$ 25,1	$\pm$ 16	$\pm$ 31	$\pm$ 5	$\pm$ 10	2,18
3	LTT _{max}	0,947 $\pm$ 0,051	1,234 $\pm$ 0,151	0,152 $\pm$ 0,036	0,452 $\pm$ 0,106	$\pm$ 16	$\pm$ 37	$\pm$ 5	$\pm$ 12	1,81
	LTR _{max}									
4	LTT _{min}	231 $\pm$ 15,3	196 $\pm$ 26,8	45,8 $\pm$ 10,8	80,5 $\pm$ 19,0	$\pm$ 20	$\pm$ 41	$\pm$ 7	$\pm$ 14	1,13
5	LTR _{min}	306 $\pm$ 30,0	182 $\pm$ 22,1	90,0 $\pm$ 21,2	66,4 $\pm$ 15,7	$\pm$ 33	$\pm$ 37	$\pm$ 10	$\pm$ 12	3,33
6	LTT _{min}	0,841 $\pm$ 0,120	1,332 $\pm$ 0,367	0,360 $\pm$ 0,085	1,101 $\pm$ 0,259	$\pm$ 43	$\pm$ 83	$\pm$ 14	$\pm$ 28	1,27
	LTR _{min}									

between muscular tension and muscular relaxation are presented in /165
Tables 17 and 18.

A tendency toward the lowering of indices of latent time (LT) after the experiment is apparent.

One of the more probable causes of such a leveling off of changes of mean LT values for various muscles is evidently the multidirect-
edness of these changes for muscles of anatomical antagonists and con-
tralateral muscles, noted for subject M. after the experiment. This
is apparent after comparison of the values of LTT maximum of the right
sural and tibial muscles, of the right rectus and bicep muscles of
this hip, of the right and left tibialis muscles of the right and left
rectus of the hip; LTT minimum of the rectus muscle of the left rectus
and bicep muscles of the hip, of the right and left bicep muscles of
the hip (Table 17).

It is necessary to note the primary increase in the LTT/LTR
index, evidencing, according to V.L. Fedorov, the improvement of the
balance between the excitatory and inhibitory components. The combined
multidirected changes in this index for muscles again shows the cross
character of the phenomena of an altered regimen ($LTT_{\max}/LTR_{\max}$ for
right and left biceps, for left sural and biceps muscles; $LTT_{\min}$ and /166
 $LTR_{\min}$ for right and left sural of right sural and bicep muscles,
for right and left bicep muscles of the thigh, for left rectus and
bicep muscles of the thigh).

Attention is drawn to the elevation of LTR indices and a de-
crease in the LTT/LTR index (for both minimum and maximum values)
of the biceps of the left arm, the only muscles of the upper extremi-
ties whose change in the temporal characteristics EMG can be regis-
tered (Table 18). Greater fluctuation of indices characterizing
muscular endurance are observed for subject S. Thus for 8 tests of
separate muscular groups (flexor and extensor of the trunk, the hip,
the forearm and the calf and flexor of the shoulders) in 5 instances
a lowering of endurance occurred, and in 3 instances there were no
changes. For the two other subjects, in 5 out of 8 instances there
was an increase and in 2 a decrease, and once the indices remained
unchanged. A lowering of endurance of the basic muscle group for
subject S. is explained, evidently, by the fact that he was not as
trained as the other subjects to these difficult experiments. No
less significant in the lowering of muscular endurance for subject
S. was the fact that he, in contrast to the other subjects, did not
always complete the program of physical exercises fully, especially
those movements which were calculated for this quality.

Thus fluctuation in muscular strength, endurance of muscle-
joint sensitivity and temporal intervals in the process of experi-
ment could be explained by the complex restructuring of daily rhythm
of physical functions. In this restructuring the distribution of
sleep in the day preceding the investigation was of great signifi-
cance.

Comparison of the characteristics of cluctuations of indices of muscular tension and relaxation before and after the experiment permits one to note a significant growth of variability of all indices under the influence of unusual circumstances of the experiment. The fact that the subjects' regimen of life activity was significantly altered, both in duration and in distribution of hours of work and rest (18-hour daily rhythm), had a great significance on the changes in these indices. /167

At the same time, the regimen of work and rest and various alterations in sleep and activity did not lead, by the end of the experiment, to an essential change in the strength and endurance of the basic muscle group, with the exception of several separate muscle groups, which indicates evidently that the subjects' motor activity was correctly organized. The organism's adaptation to such an alteration of work and activity periods, in which the daily rhythm is sharply altered (according to indices of precision and resistance of temporal-strength responses) takes place slowly (on the 10th and 13th day). In addition, the usual periodicity of changes in physiological indices is established.

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